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ABSTRACT

This book presents information on career opportunities in civil engineering. Chapter 1 focuses on the scope of civil engineering, discussing: role of scientist, engineer, and technologists; engineering and engineering technology; civil engineer's role and obligations; and other information. Chapter 2 considers such aspects of the education for civil engineers as high school requirements, selecting a college/university, curricula, graduate/undergraduate programs, continuing education, educational costs, and financial aid opportunities. Civil engineering specialties are considered in chapter 3, focusing on structural engineering, structural mechanics, transportation engineering, water resources engineering, geotechnical engineering, and others. Job duties, salaries, and working conditions are considered in chapter 4. Areas discussed include specific job duties, typical assignments for beginning engineers, responsibilities of experienced professionals, wages/salaries and fringe benefits, general employment conditions, and overall demand (past, present, future) for civil engineers. Among the areas discussed in chapter 5 (employment and advancement) are the job market, selecting the right job, opportunities for females and minority groups, membership in professional organizations, and personal development through a civil engineering career. Professional organizations in civil engineering are discussed in chapter 6. General technical publications, recommended lists of general technical publications, recommended readings, sources of additional career information, and accredited schools are included in appendices. (JN)

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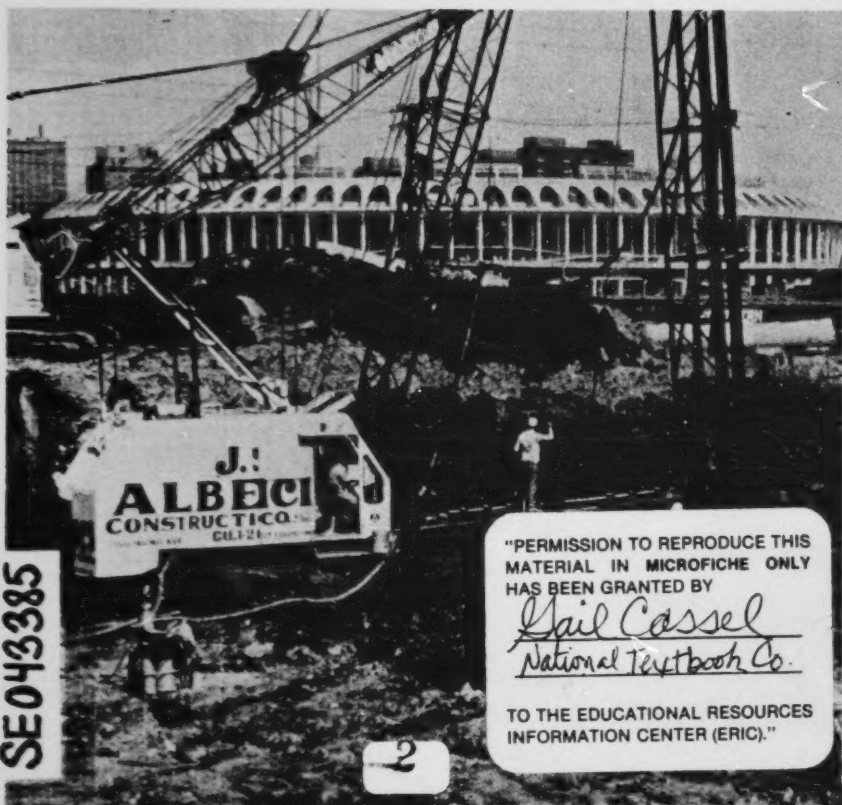
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OPPORTUNITIES IN CIVIL ENGINEERING

D. Joseph Hagerty
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OPPORTUNITIES IN CIVIL ENGINEERING

**D. Joseph Hagerty
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Dedicated
to
Nathan M. Newmark and Ralph B. Peck
ADVISORS, FRIENDS AND
EMINENT CIVIL ENGINEERS

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CHAPTER 1

THE SCOPE OF CIVIL ENGINEERING

The general role of engineers as persons utilizing natural resources to better human living conditions was mentioned very briefly in the introduction. In this chapter, more detailed and comprehensive definitions of engineering and more specifically, civil engineering, will be given. Engineering is closely related to the broader field of technology, which, briefly defined, is the application of science to the solution of real problems. Since technology involves the application of science and scientific principles, it is apparent that scientists are involved in technology and their work must relate closely to the work of engineers. Technology is *applied* science, applied in a very true sense of the word in the real world. By this we mean that technology involves the application of scientific principles to the use and handling of natural materials to create a variety of things to satisfy human needs. The creation of the material goods which are the products of technology is the job of the craftsman. The craftsman is directed in this work by the engineering technician. Somewhere between the scientist searching for absolute truth and the craftsman dealing with such natural materials as wood, concrete, and steel, the engineer functions as a key member of a technological team. In order to describe the role of the engineer as a member of this team, it is necessary to emphasize certain distinguishing characteristics of scientists, technicians, and craftsmen, as well as engineers. First, we need a basic definition of engineering.

ENGINEERING

The most appropriate way to answer the question, "What is Engineering?" is to look at the answers to this question which have been given collectively by practicing engineers. The American Society for Engineering Education, in conjunction with the Engineers' Council for Professional Development, have defined engineering in the following way:

"Engineering is the profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize the materials and forces of nature, economically for the benefit of mankind."

From this definition, it is apparent that the engineer is deeply involved with the application of mathematical and natural sciences. For that reason, a great deal of confusion exists in many persons' minds concerning the distinctions between scientists and engineers. Another confusing factor is the existence of many individuals who apparently perform engineering work, applying scientific principles to the solution of practical problems, but who do not possess the general hallmarks of a professional engineer—a college degree, an engineering license or a legal registration, and membership in a professional engineering society. Also confusing are individuals who were originally trained in engineering entering other fields of activity, such as sales or management, while retaining a basic identification with the profession of engineering. In other words, many persons who function as sales representatives and as managers refer to themselves as "engineers" because their basic education and early experience were in engineering. Finally, many people, especially children, are confused by the application of the term "engineer" to persons who drive trains and to other individuals whose activities are far removed from professional engineering. In order to clear up this confusion, it is helpful to examine the characteristics of engineering which are mentioned in the definition given above.

First, engineering is a profession. By a profession, most people

mean a vocation or calling which requires the application of specialized knowledge that is gained through long and intense preparation. Most of the time, this preparation is obtained through formal education, particularly in scientific and scholarly principles. Two clear examples of professions other than engineering are those of medicine and law, which require long years of educational preparation and specialized training for successful practice.

In addition to intensive and specialized preparation, a profession has other major characteristics, including the maintenance of high standards of conduct by the members of the profession themselves through some form of organization. The members of a profession collectively police their colleagues and insist upon high standards of ethics and achievement by their fellow professionals. In many cases, maintenance of these high standards of achievement requires members of a profession to continue to study and gain experience in their fields of endeavor throughout their entire professional careers.

Finally, a profession is generally thought of as a vocation or calling to a kind of activity devoted to public service. In other words, the prime purpose of most professions is collective action by the members of that profession for the public good. It is easy to see that the day-to-day activities of doctors and lawyers are directed toward improving human living conditions and developing a more civilized society. In the same way, engineers work to develop a better quality of life for their fellow men through the application of scientific principles and their own experience in using natural resources and the forces of nature for the benefit of mankind. Many engineers are employees of large corporations or consulting firms and as such, their contributions to the public good may be somewhat hidden. Nevertheless, the effects of their activities upon community well-being are quite important. In the day-to-day life of a citizen in any of the industrialized nations of Western Europe or North America, almost everything that this person uses, touches, or eats has been influenced significantly by an engineer's activities at some stage in its manufacture or processing.

It is important to remember, in discussing the engineering profession, that much of the specialized knowledge which the engineer uses to solve real world problems has been gained through experi-

ence and professional practice. This knowledge is different from scientific knowledge which has been gained through experimentation and the use of logic to analyze the results of experiments. Experimentation and the application of logic to the analysis of problems is the job of the scientist. In many situations, the engineer may have little scientific basis for developing a design or for predicting the performance of a system. Rather, he knows from experience what will happen if a certain course of action is followed, although he may not be able to explain fully why such results are obtained. That part of the engineer's knowledge which is based upon experience is very important and significant. This characteristic of the engineer—his use of experience and accumulated practical knowledge—distinguishes him from the scientist.

The Scientist

The scientist occupies one end of the spectrum of technology; his activities as part of the technological team are quite distinct from those of the engineer, the technician, and the craftsman. The scientist's basic purpose is to discover knowledge, to uncover new facts, and to learn more truths about the natural world. The scientist attempts to explain the facts that he discovers by developing new theories which relate causes and effects in the natural systems he has observed and investigated. The scientist seeks to *know* rather than to *apply*. His principal concern is not the application of the new knowledge he has discovered but simply the discovery of that knowledge itself. Some scientists are called "applied scientists" because they are interested in developing applications of scientific methods, but the basic activity of even these scientists remains the discovery of new knowledge.

Some scientific disciplines work closely with other technological professions in the application of discovered knowledge to better the welfare of man. In this way, they hope to direct their research efforts to uncovering facts which will be most important to human welfare. For example, geologists and chemists have worked for many years with engineers and technicians in applying scientific knowledge to the discovery of more facts about the geology and chemistry of the

earth. At the same time, they attempt to apply the knowledge they have gained about the earth to enable engineers and technicians to utilize more efficiently the resources present in the earth's crust. Likewise, in recent years, mathematicians and physicists have devoted much of their time to the application of scientific methods in the solution of practical problems, rather than simply to the discovery of additional facts. Nevertheless, in the overall picture, the principal mover in the application of scientific knowledge is not the scientist, but the engineer.

The Engineer

As mentioned previously, the engineer is interested primarily in the *application* of scientific knowledge and his own experience rather than in the discovery of new knowledge through scientific investigations. The engineer is interested in both the natural world and in the artificial world created by man. The engineer designs and plans developmental projects, production processes, operations and maintenance procedures, etc. His activities are directed primarily toward planning and designing *systems* to achieve certain results. Obviously, from the statements that have been given in previous paragraphs, the engineer is striving to achieve results that will benefit society. However, the engineer goes beyond the simple purpose of benefiting society and strives to achieve this benefit to the public at a minimum cost in money, materials, and time. The engineer attempts to forecast the behavior of the systems he has designed in an effort to achieve the most efficient results. He attempts to assess and predict the benefits and costs of the activities he has designed and planned. In general, he does not assume the immediate responsibility of seeing that his designs and plans are implemented. That is the job of the technician.

The Technician

The technician has the primary responsibility of seeing that the engineer's designs and plans are implemented. The engineer is concerned chiefly with *designing* and *conceiving* plans and systems; the

technician is concerned principally with *doing* and *making*. The technician may be involved in time-and-motion studies in an effort to achieve the most efficient application of a process developed by an engineer. A technician may be the supervisor on a construction project where the proposed facility has been designed and planned by an engineer and an architect. In general, the technician is more concerned with a particular application of experience or scientific principles to achieve a specialized goal or result than is the engineer, who is often engaged in planning complex systems. The technician utilizes science and mathematics in much the same way as does the engineer. However, the technician attempts to solve specific, small-scale, often repetitive problems which are contained within the broad framework of the designs and plans developed by the engineer. Typically, he utilizes instruments and devices to measure and monitor the quality and performance of completed systems. However, his principal activity is not the use of tools; rather, the technician is charged with seeing that the designs and plans developed by engineers are implemented, with machines and materials, by craftsmen.

The Craftsman

The skilled craftsman is at the opposite end of the technology spectrum from the scientist. The craftsman uses his hands and skills just as much as he utilizes his mental processes. As an artisan, he is seldom called upon to utilize scientific principles or scientific knowledge. Rather, he is much more likely to use tools with a skill developed through experience gained during his own lifetime on the job, or imparted to him from his coworkers. Some of his skill in utilizing tools may be based upon simple manual dexterity or an intuitive feel for material behavior and performance. Craftsmen include electricians, machinists, carpenters, masons, and many others. The importance of the craftsman as a member of the technology team should not be underrated. To a great degree, the overall success of technical systems depends upon the skill of the craftsman in utilizing tools to build and maintain engineered systems. The craftsman's concern for good workmanship in construction and for proper use of completed

systems is extremely important to the proper functioning of those systems.

PERSPECTIVE

The activities of the engineer can now be seen in the context of his position as a member of a team of specialists engaged in applying scientific knowledge and practical experience to the solution of technical problems. However, the engineer also must consider many non-technical factors in developing plans and designs. These non-technical factors include the legal restraints on proposed activities and the social impacts which would be produced if proposed designs and plans were implemented. Further, the engineer must consider economic factors and must try to develop the most efficient and least expensive answer to a particular problem or need. Finally, the engineer must be aware of aesthetic considerations and must realize that, in order to truly benefit society, his solutions must reflect a proper appreciation for style and grace. The best use of natural forces and materials to benefit mankind is attained through structures, machines, and facilities which are aesthetically pleasing as well as functional.

From the definitions and comments given in the preceding paragraphs, it should be apparent that the primary purpose of the engineer's work is to benefit society. This effort to better the conditions of life for mankind is perhaps the greatest contribution members of the technology team can make. The idea and practice of utilizing natural forces and materials to improve the conditions of human life certainly is not new; it is as old as civilization itself. However, in recent years the application of scientific knowledge (which greatly increased during and since the Industrial Revolution) has produced a very complex technology.

It has been estimated that more scientific knowledge has been gained about the natural world since 1900 than had been obtained in all previous history. People today are witnessing more and more numerous and varied applications of science. Nevertheless, the basic purposes for these applications of scientific fact have their roots in antiquity. Engineers were working for the benefit of mankind even

before there were such names as *scientist*, *engineer*, and *technician*.

SOME CIVIL ENGINEERING HISTORY

One of the outstanding figures of the seventeenth and eighteenth centuries was King Louis XIV of France. He is important to the growth of engineering since he was persuaded by his minister Colbert to establish academies of sciences and architecture in the late 1600s and to establish the Corps de Genie, a group of military engineers. This group of engineers was to be given a scientific education under the direction of Vauban, the foremost military engineer in France at that time. By establishing an engineering corps for the French army, King Louis set a trend calling for the scientific education of engineers and thus emphasized the application of scientific principles to engineering practice.

Louis XIV was a farsighted monarch who did not concentrate entirely on military matters; rather, he devoted considerable money and effort to developing commerce and manufacturing in France. A major part of this effort was the planning and construction of a system of public highways and canals to improve internal communications in France. He built a canal to connect the Mediterranean Sea with the Atlantic Ocean and developed a system of highways leading to Paris from all parts of the country. He succeeded in paving and lighting the city of Paris at this same time. All of these activities were accomplished by engineers who may have been trained in the building and maintenance of fortifications and other military structures, but who now undertook work of more civilian character.

During this time and in the next century, while French engineers were being trained in a more scientific fashion, their counterparts in the British Isles were still relying heavily on experience and field training. British engineers, during the seventeenth century, learned much from the Dutch engineers brought into England to assist in major drainage projects. During the eighteenth century, the development of this body of British engineers devoted to civil works continued. This development led to the formation of what can probably be considered to be the first body of professional civil engineers

when an engineering society was formed by John Smeaton, in 1771. Smeaton was a pioneer in the field of civil engineering not only because he formed the first society of engineers engaged in civil works, but he apparently was the first engineer using the English language to put the title "civil engineer" behind his name to designate his profession. Smeaton also was the first individual to appear as an expert witness to give testimony in a lawsuit, where the verdict was greatly influenced by a technical opinion. Although formal education in engineering was established at the University College in London in 1828 and later in other schools in the British Isles, much of the civil engineering work which was carried out at this time in Great Britain and the American colonies was still being accomplished by educated men who had obtained their knowledge through reading periodicals and scientific journals or who had practical experience in field construction and operation projects.

The emphasis on engineering, in the infancy of the United States, was placed on military engineering; the Continental Congress authorized an engineering corps for Washington's army in 1775. This emphasis on military engineering changed, however, after the Revolution. In 1794, Congress authorized President Washington to recruit a body of engineers to design and construct fortifications around harbors on the Atlantic seacoast. This work led to the improvement of the harbors themselves, a project civil rather than military in character. In 1807, Congress recognized the need for a survey of the coastline of the United States and appropriated funds to employ a group of surveyors and engineers for this important work. Finally, in 1824, Congress appropriated funds and authorized surveys for roadways and canal routes which were considered important by the President at that time. These surveys were to be the responsibility of the U.S. Army Corps of Engineers. This increasingly important civilian role in engineering continued to be evident with the coming of the railroads in the mid-nineteenth century and the development of the Industrial Revolution.

Today, civil engineering stands apart from military engineering and from other branches of engineering. Basically, civil engineering consists of the planning, designing, construction, and operation of physical facilities and structures. These facilities may include

bridges, highways, airports, and other facilities for transportation. Civil engineers plan, design, and supervise the construction and operation of dams, floodwalls, irrigation works, harbors, and other waterways. Obtaining and purifying water supplies for the general public, as well as treating wastewaters, are included among the activities of civil engineers. Civil engineers are active in the design and construction of industrial buildings, power plants, office buildings, and major residential complexes. In all of these areas, civil engineers are active in research to further expand the body of knowledge which exists at the present time. In these efforts, they work with such scientists as geologists and physicists, such non-technical personnel as economists and city planners, and engineers from other branches of the profession.

Other Branches of Engineering

After the field of civil engineering was formally established in the late 1700s, almost all engineers were considered to be either civil engineers or military engineers. However, with advent of steam-driven machinery in the eighteenth and nineteenth centuries, the need arose for an engineer who was particularly educated and experienced in the application of scientific principles to the design, control, and operation of machines. To satisfy this need, a new class of engineer appeared—the mechanical engineer. The power of flowing water and, later, the power from expanding steam were utilized to drive machinery to accomplish tasks previously carried out by individual workers. This application of water and steam power led to the Industrial Revolution. To successfully utilize water and steam power, it was necessary to develop dependable engines; this, in turn, required better quality control for the materials used in the engines, as well as more thorough planning in the construction and operation of manufacturing systems in factories. All of these activities were undertaken by a class of professionals who became known as mechanical engineers.

In the latter part of the nineteenth century, other technological developments of great importance were taking place, in addition to the application of water and steam power to drive machinery. Scien-

tific investigations of static electricity, begun by Benjamin Franklin, were intensified and extended. These investigations led to the successful generation of usable electrical power. Generated electricity was applied in a variety of ways; city streets were illuminated with electric arc lights in the 1880s, giving dramatic emphasis to the importance of technology in improving the quality of human life.

In the last half of the nineteenth century, the increased interest in chemical processing generated by the Industrial Revolution led to the development of a great chemical industry. The use of chemicals in processing materials and in manufacturing goods, and the need to develop new chemical compounds to meet specific needs, required some of the skills of the civil and mechanical engineers who were in practice at that time, but also required many of the skills of industrial chemists. To satisfy these needs, another group of professionals emerged who are known today as chemical engineers.

The electrical energy which was applied to domestic and industrial uses for the first time in the 1870s and 1880s required technical management. A scientific knowledge of the flow of electrical energy through materials and through space was not sufficient for the solution of practical everyday problems in electric power generation and transmission. To satisfy this need, a body of engineers gradually emerged who were involved in the application of electrical power in industry and in domestic uses such as illumination. These engineers today are called electrical engineers. Their work is distinct from, but closely related to, the work of electronics engineers. The flow of electrons in a vacuum had been investigated as early as 1880 by Edison and his contemporaries. During the early years of the twentieth century, Fleming, and later DeForest, developed devices to control the flow of electrons in a vacuum. These vacuum tubes were the basis for a rapidly expanding field of specialization called *electronics*. Electronics today are utilized in many different ways, but principally in communications between persons, and between persons and machines.

Many other new branches of engineering have appeared in the twentieth century. For example, the discovery of atomic energy has led to the development of a new branch of engineering directed toward applying this great source of power for the benefit of society.

Persons engaged in this work are called nuclear engineers. More recently, engineers have become more involved with scientists in hybrid disciplines such as environmental engineering, biomedical engineering, and geological engineering. During the last several decades, the number of specializations within the general field of engineering has increased greatly, and the future should see even more specialization.

FUTURE OUTLOOK

The history of engineering, and the development of civil engineering as a separate branch, have been described in the preceding pages. What does the future hold for the civil engineers? Will their roles as members of the technology team continue to be important ones? What will be their duties and rewards in coming years? These questions can be answered in a very definite, positive way.

Employment. The future prospects for employment in civil engineering appear to be extremely promising. The demand for civil engineers, as well as for all types of engineers and technicians, is increasing daily. According to a publication of the U.S. Department of Labor, *U.S. Manpower in the 1970s—Opportunity and Challenge*: "In this decade, as in the past, the fastest growing occupations are professional and technical, the ones requiring the most education preparation. This occupational group will increase by 50 percent by 1980." Other studies have shown that the number of engineers in the United States increased from approximately 870,000 in 1960 to more than 1,200,000 in 1970, an increase of more than 40 percent. Engineers are one of the most numerous professional groups; only elementary and secondary school teachers (2,800,000 in 1970) outnumber engineers. Continuing demands for technically educated personnel indicate that another 20 percent increase in the number of engineers will be necessary to meet national needs during the decade of the 1970s. By 1980, in all probability, there will be more than 1,500,000 engineers in the United States. Of this total number of engineers, approximately 20 percent will be civil engineers.

The enrollment of students in engineering programs in colleges

and universities in the United States increased greatly in the 1960s. This was the result of the emphasis on engineering created by the space program and the publicity associated with the launching of satellites and the exploration of space. However, enrollment in technical curricula declined during the early 1970s and, in 1973, reached its lowest level in 20 years. In the last three years, on the other hand, enrollments in engineering have increased sharply. This increase in enrollments has occurred in response to the obviously increasing need for engineers and technicians in American society today.

The decline in engineering enrollments mentioned in the previous paragraph was not reflected in a similar decline in civil engineering enrollments. On the contrary, in the last ten years enrollment in civil engineering programs in colleges and universities has continued to grow steadily. The number of engineers graduating from civil engineering programs also has increased greatly. For example, in 1968, approximately 5,500 bachelor's degrees were granted in the field of civil engineering, out of a total of approximately 35,000 bachelor's degrees in all fields of engineering. By 1975, out of a total of more than 38,000 bachelor's degrees in engineering, approximately 7,900 degrees were granted in civil engineering; civil engineering graduates thus amounted to about 15 percent of the total number of graduates in engineering programs in 1968, but accounted for approximately 21 percent of the engineering degrees granted in 1975.

Projections made by the United States Department of Commerce indicate that if the employment trends currently existing in the United States continue for the next five years, approximately 236,000 civil engineers will be required to fill the demand for such specialists by 1980. If the present status of the economy is changed to reflect more emphasis on defense and military projects, including space exploration, this demand has been estimated at 233,000. If, on the other hand, the economy in the United States is changed to reflect more concern for social welfare and environmental quality, the demand for civil engineers would be increased to about 257,000. In general terms, regardless of the direction of the economy, approximately 50,000 graduates in engineering will be required each year for the next ten years to fill this need for engineers. At the present time, only about 38,000 engineers are graduated from American

schools each year. It should be obvious that civil engineers, in the 1970s and 1980s, should have no problem finding employment. The employment situation of engineers in the 1970s and early 1980s has been described very well by Betty Vetter, executive director of the Scientific Manpower Commission—"... we will still be trying to erase urban blight, produce adequate clean energy, purge the environment, create effective transportation systems, and provide adequate health care, while maintaining our national defense and continuing some level of space exploration."* Obviously, all of these activities will require the employment of considerable numbers of engineers, particularly civil engineers.

Salaries

Salaries and other rewards will be described in more detail in Chapter 4 of this book. However, a brief word can be said at this point, indicating the future outlook for salaries in civil engineering. In general, the outlook for civil engineering salaries is extremely good. On the average, civil engineers earn slightly less than the average of all engineering professionals. This fact is principally a result of the employment situation of most civil engineers in the United States today. A great number of civil engineering graduates find employment with city, state, and federal governments, and in those positions, they earn slightly lower salaries than do engineers in other branches of engineering who are employed by industry or who are self-employed. However, an appreciable percentage of all civil engineers are employed in consulting firms, or they are self-employed as consultants. These individuals earn salaries which are significantly higher than the average of all engineering salaries.

Starting salaries for engineers with bachelor degrees have risen steadily from an average of approximately \$3,000 per year in 1945 to more than \$13,000 per year (average starting salary) in 1975. Of course, much of this increase in salaries can be attributed to the increase in the cost of living. However, if the increases in the cost

*Betty Vetter, "A Bubble in the Educational Pipeline," *Science*, April, 1972.

of living over the last 30 years are taken into account, it is apparent that beginning salaries for engineering graduates today are approximately double the salaries paid to new engineering graduates in 1945. In addition, the accumulation of experience in a particular engineering field inevitably will lead to higher salaries. For example, several recent studies of engineering salaries indicate that engineers with 20 years' experience earn approximately 70 percent more than recent graduates, if they are employed in non-supervisory capacities. For engineers who are engaged in supervisory capacities, the accumulation of 20 years experience, on average, leads to salaries more than double those of recent engineering graduates. The relative position of engineers' salaries with respect to those of other professional people and non-professionals has been the subject of a number of studies by engineering societies and by the federal government. In the last 25 years, these studies show that engineers and other technical professionals have moved up in income level when compared with other professionals, farmers, owners of small businesses, and blue-collar workers. Engineers now constitute approximately 20 percent of the top income level group in the United States. (This top income level group is considered to be those persons whose earnings, in the form of salary and other income, exceed those of 95 percent of all the wage earners and professionals in the United States.) Civil engineering salaries will be described in more detail in Chapter 4.

Education

The future outlook for education in civil engineering includes an increased emphasis on advanced education, especially graduate level education. This trend is exemplified by the growth of five-year programs in civil engineering, leading to a master of engineering degree. It is the collective feeling of many civil engineers in education and in practice, that at least five years are required for proper education in the profession. Additionally, many engineers feel that some practical experience or internship must be made a part of civil engineering education.

To obtain this practical experience while obtaining a civil engineering education, many students enroll in schools which maintain

cooperative education programs. In these cooperative education programs, engineering students are placed in jobs with engineering firms, government agencies, and in other positions where they will gain valuable on-the-job experience in engineering. At the same time, these students earn money which can be of vital assistance in paying educational costs. The practical experience in engineering which these students obtain during their college years gives them a better perspective on the profession of engineering. Some may find that their ideas of engineering do not match their experiences in engineering. They can, at this point, decide to continue their studies in another field more suited to their interests. On the other hand, if they find that the practice of engineering is interesting and stimulating to them, they are likely to find their continued studies in engineering more interesting and, consequently, easier.

In addition to increasing emphasis on cooperative education and professional school education (five-year programs), in the future, there is likely to be much more emphasis on continuing education of graduated engineers. At the present time, several state legislatures are considering changes in licensing laws which will require engineers to continue their education through seminars and short courses in order to maintain their professional registrations. Professional registration, the official recognition by an examining board of an individual's qualifications to practice as an engineer, is extremely important to many engineers, especially civil engineers. Thus, requirements for continuing education to maintain professional registration are likely to be very important in the coming years. In any case, conscientious engineers will undoubtedly continue their education after their graduation from engineering school. Many of these individuals will elect to return to a college or university to pursue an advanced degree in engineering or in a non-technical field which may be related to their job duties. Some individuals will return to engineering colleges on a temporary basis, or for short periods of time to attend seminars, conferences, and short courses devoted to particular topics of interest. Other engineers will find the opportunity available for continuing education through the agency or company where they are employed. In all of these cases, continuing education is likely to become more and more important in the coming years.

Finally, in the future, the role of minorities in civil engineering should be greatly expanded and increased. Information on college enrollments in engineering indicates an increasing interest on the part of women, blacks, and other minority groups, in engineering and technical education. This interest certainly includes the field of civil engineering. In 1975, approximately 18 percent of all the bachelor's degrees in engineering awarded to women were civil engineering degrees, and approximately 13 percent of all bachelor's degrees awarded to blacks were civil engineering degrees. Additionally, approximately 17 percent of all master's degrees awarded to members of minority groups in 1975 were civil engineering degrees. This increasing role of minorities in civil engineering reflects an increasing interest in this important profession as well as an expansion of opportunities for such individuals.

CONTRIBUTIONS AND OBLIGATIONS

The descriptions of the activities of engineers, and particularly civil engineers, which were given in the preceding pages should indicate that the contributions of civil engineers will be very important to the improvement and maintenance of the quality of life in today's complex technological society. Because of the great expansion of scientific knowledge in recent years, the basis for applying science has been greatly expanded, and much non-scientific knowledge has been gained by experience. Civil engineers will find it necessary to use scientific principles and their own accumulated experience in conceiving plans and designs for physical systems and facilities. In making these contributions to society, civil engineers will have definite obligations.

In formulating designs and in solving practical problems, engineers seek to use available resources in the most efficient and effective way in order to achieve the greatest benefit for man. The natural resources which are available to engineers are energy, materials, and human resources. Energy can be obtained from the sun, from fossil fuels, from nuclear reactions, and from other sources, such as hydro-

electric power and wind power. Some of these forms of energy are renewable; others are not. Therefore, engineers must be concerned with utilizing non-renewable resources in the most efficient way possible and, whenever possible, utilizing renewable resources rather than those which are limited and cannot be replaced.

Also, in achieving solutions to technical problems, engineers must be aware of the social and political conditions which have a bearing on their work. For example, certain energy resources and raw materials are found only in limited areas of the earth. In some cases, the inhabitants of those areas may not be willing to share their resources with others. Thus, a social and political constraint is imposed upon the work of engineers. Social and political factors must enter into the solution of technical problems in order for the solutions to be workable in the real world. Consequently, engineers, and particularly civil engineers who so often deal with public works projects, must not be ignorant of the social and political implications of their activities.

Finally, in recent years, an awareness has developed of the fragile relationship between man and his environment. There is a growing realization of the limits of the earth with respect to natural resources and the purity of the atmosphere, the waters of the earth, and the land itself. It is no longer sufficient for an engineer to identify a material need in society and to develop a product to satisfy that need. It is necessary now to consider if satisfying that particular need will lead to a general benefit or will lead to a decrease in the quality of life. It is now necessary to consider various alternative ways to accomplish certain purposes. In this consideration of alternatives, it is necessary to consider social and aesthetic implications and effects. For example, building a dam to create a lake along the valley of a mountain stream may produce a definite benefit in the form of the power supplied through turbines installed in the dam. However, construction of this dam may also rob the inhabitants of the region of an important recreational area and may eliminate a wilderness habitat important to many other forms of life. Obviously, it is necessary to consider the total effects and impacts of any proposed solution to a technical problem. To assist engineers in judging the effects of their activities and to assist them in making

decisions about the proper course of action to follow in any given situation, the National Society of Professional Engineers has developed a Code of Ethics.

Code of Ethics

The major sections of the Code of Ethics are given below:

Preamble

The Engineer, to uphold and advance the honor and dignity of the engineering profession and in keeping with high standards of ethical conduct: will be honest and impartial, and will serve with devotion his employer, his clients, and the public; will strive to increase the competence and prestige of the engineering profession; and will use his knowledge and skill for the advancement of human welfare.

The Engineer will be guided in all his professional relations by high standards of integrity, and will act in professional matters for each client or employer as a faithful agent or trustee.

The Engineer will have proper regard for the safety, health, and welfare of the public in the performance of his professional duties. If his engineering judgement is overruled by non-technical authority, he will clearly point out the consequences. He will notify the proper authority of any observed conditions which endanger public safety and health.

The Engineer will avoid all conduct or practice likely to discredit or unfavorably reflect upon the dignity or honor of the profession.

The Engineer will endeavor to extend public knowledge and appreciation of engineering and its achievements and to protect the engineering profession from misrepresentation and misunderstanding.

The Engineer will express an opinion of an engineer-

ing subject only when founded on adequate knowledge and honest conviction.

The Engineer will undertake engineering assignments for which he will be responsible only when qualified by training or experience; and he will engage, or advise engaging, experts and specialists whenever the client's or employer's interests are best served by such service.

The Engineer will not disclose confidential information concerning the business affairs or technical processes of any present or former client or employer without his consent.

The Engineer will endeavor to avoid a conflict of interest with his employer or client, but when unavoidable, the engineer shall fully disclose the circumstances to his employer or client.

The Engineer will uphold the principle of appropriate and adequate compensation for those engaged in engineering work.

The Engineer will not accept compensation, financial or otherwise, from more than one interested party for the same service, or for services pertaining to the same work, unless there is full disclosure to and consent of all interested parties.

The Engineer will not compete unfairly with another engineer by attempting to obtain employment or advancement or professional engagements by competitive bidding, by taking advantage of a salaried position, by criticizing other engineers, or by other improper or questionable methods.

The Engineer will not attempt to injure, maliciously or falsely, directly or indirectly, the professional reputation, prospects, practice or employment of another engineer, nor will he indiscriminately criticize another engineer's work in public. If he believes that another engineer is guilty of unethical or illegal practice, he shall present such information to the proper authority for action.

The Engineer will not associate with or allow the use of his name by an enterprise of questionable character, nor will he become professionally associated with engineers who do not conform to ethical practices, or with persons not legally qualified to render the professional services for which the association is intended.

The Engineer will give credit for engineering work to those to whom credit is due, and will recognize the proprietary interests of others.

The Engineer will cooperate in extending the effectiveness of the profession by interchanging information and experience with other engineers and students, and will endeavor to provide opportunity for the professional development and advancement of engineers under his supervision.

Persons who aspire to the engineering profession must possess high moral principles and a full measure of integrity. In addition to excellent character, an individual also must possess other attributes in order to be a successful engineer.

PERSONAL ATTRIBUTES

In order to determine if you are suited to a career as a civil engineer, it is necessary for you to examine your character and interests, especially with regard to three areas—interest, ability, and ambition. In other words, if you hope to be a successful engineer, you must be sufficiently interested in the field, must possess the proper capabilities, and must have sufficient drive and perseverance to succeed. Of these three factors, perhaps the most important is the amount of interest you have in a particular career. Any type of work which greatly interests you will probably be the type of work at which you most likely will succeed. On the other hand, work or duties which you consider boring, uninteresting, or unimportant, will be very difficult for you to perform.

In order to discover where your interests lie, it is necessary for you

to review your life in an attempt to see what ideas or activities have aroused your curiosity and attracted your interest. With respect to engineering, it is important to consider any interest you may have in the operation of electrical or mechanical devices, or in technical and scientific developments. Are your hobbies related to scientific and technical activities? Do you like mathematics and mathematical puzzles? In previous reading about various career fields, have you found the descriptions of engineering to be interesting or boring? If you have ever visited a construction project, a manufacturing plant, or a design office, were you interested in the activities of the technical personnel employed in those places? Have you asked any engineers, particularly civil engineers, about their work? Have you tried to learn as much as possible about the field of civil engineering? The answers to all of these questions can go a long way toward indicating whether or not you truly have a significant interest in engineering, and in particular, civil engineering.

In addition to a serious interest in the field of engineering, a prospective civil engineer must have certain capabilities in order to be successful. Among these capabilities is an easy mastery of mathematics and the application of mathematical principles to the solution of practical problems. You should ask yourself: "How good am I at stating problems in quantitative terms and in obtaining quantitative or numerical solutions? Can I translate real situations into abstract terms or symbols without becoming confused? Do I understand the various number systems which are employed in mathematics?"

In addition to these questions about mathematics, you should examine your interests and successes (or failures) in such related fields as physics and chemistry. Do the principles of physics interest you, as a prospective engineer, and can you find any applications of these principles in the real world? Can you understand such concepts as force, mass, acceleration, leverage, gravitation, and other abstract physical principles? Also, are you interested in studying the chemical formulation of compounds and the way in which various elements combine in nature? It is easy to answer these questions through an examination of high school academic records, particularly with relation to grades in science and mathematics courses.

High scores and excellent grades in mathematics, physics, and chemistry usually indicate that a person has the capability and interest to undertake engineering studies with a significant hope for success.

Other capabilities and aptitudes, in addition to academic capabilities, also are necessary for a successful career in engineering. One of these abilities is the capability of visualizing in concrete terms what is described only in words. If you are interested in a career as an engineer, you should consider whether or not you are able to describe in words, and to illustrate in sketches, complex actions or processes. For example, would you be able to describe in words and illustrate in a few simple sketches, the mixing of fuel and air in the carburetor of an internal combustion engine? Could you show in a simple sketch the way in which an airplane wing works to lift the aircraft? Ability to communicate, both orally and on paper, is very important to success as a civil engineer. As a potential engineer, you should consider whether or not you are able to relate well to others. It is essential that an engineer who works as a member of a large team be able to get along well with other people and communicate effectively with them. In considering a career in civil engineering, you should examine your own past performance in working together in groups with other persons to accomplish specific goals and objectives.

Note carefully that none of the qualifications described in the preceding paragraphs are at all related to sex or racial background. Any person capable of developing abstract concepts, of dealing effectively in quantitative terms with physical processes, and of communicating effectively with others can succeed in a career as an engineer. As mentioned previously, there is no reason to expect that members of minority groups would have any trouble in obtaining interesting employment at more than adequate salaries in the field of civil engineering in the immediate future and for a long time to come. Members of minorities will find, in the field of engineering ample opportunity for employment and advancement. This advancement will occur, if the person performs as expected, whether or not that person is employed by federal or state governments or by private industry. On the technological team, a person's capabilities to produce are much more important than his sex or race.

If you are seriously interested in civil engineering and feel that you possess the necessary skills for a career in civil engineering, there is an excellent chance that you will succeed, if you are correct in your judgments and are willing to work and persevere in your efforts. Working in technical fields is difficult and at times, very exacting. As a prospective civil engineer, you will be called upon to master a great deal of technical information and understand many technical concepts. You must be capable of applying yourself to work in an efficient way, constantly improving your efforts. If you can do this and if you possess sufficient drive and ambition, you will succeed in a civil engineering career just as you would in any other career field. On the other hand, a careless or lazy individual can no more succeed as a civil engineer than he can succeed in any other profession. If you are about to graduate from high school and are considering civil engineering as a career, you should ask yourself the following questions: "Do I complete my study assignments on time? Do I need urging by others to complete an assigned task? In solving assigned problems, do I avoid a technical portion of a problem, do I avoid obtaining definite numerical answers? In general, do I get the job done?" The answers to these questions will indicate your potential for success in a career as a civil engineer.

CHAPTER 2

EDUCATION FOR CIVIL ENGINEERS

In considering a career in civil engineering, there are a number of questions that you must ask yourself—What should I study in high school if I want to attend engineering school? How do I decide which college or university is best for me? What will I study if I do enter an engineering school? What types of programs are available if I choose to make my career in the profession of civil engineering? In this chapter, these questions and others will be answered in order to help you learn as much as possible about the field of civil engineering.

It must be noted at this point that the education of a civil engineer begins with the study of English and arithmetic in grade school. It ends only at retirement or termination of practice. Between these two end points, engineering education progresses from a study program with emphasis on the details of technology and the sciences to the acquisition of years of experience with emphasis on concepts, judgments, and administration. During the period in which a professional engineer is acquiring knowledge and applying it in practice, the four to seven years of formal education in a college or university is only a brief interlude in his training in technical and non-technical subjects.

The formal study of civil engineering can be characterized as having several goals. A well-rounded curriculum should prepare students for the productive practice of the civil engineering profession. It should provide sufficient mathematical, scientific, and non-technical background to permit continuing self-education throughout their careers. It should introduce students to the social, political, and economic sciences so that, in the future, as civil engineers, they will

be capable of working with specialists in these areas and of developing engineering designs which serve the broad interests of society. Finally, an engineering curriculum must provide adequate preparation for exceptionally capable students to continue their education beyond the first professional degree.

HIGH SCHOOL

Today, the profession of engineering is changing rapidly. New knowledge in all fields of engineering, as well as in the specific field of civil engineering, is being made available at an astonishing rate. Engineering education, in attempting to cope with these rapid changes, has become more complex and more difficult. New engineering graduates must possess a sound educational background in the physical sciences, in mathematics, and in communication skills; therefore, high school preparation should basically be geared toward these areas. A sound background in English communication, mathematics, and physical science will be required for entrance into college level engineering programs. As members of technological teams, engineers will be required to communicate with other persons on those teams and with members of the general public. Therefore, they must have a good command of the written and spoken language. Additionally, since mathematics is a basic tool and is used so frequently by engineers, it is important to have a good secondary school preparation in this area.

Therefore, it is quite important for you, as a prospective engineering student, to begin as early as possible to develop your high school education according to the requirements for an engineering career. Unfortunately, many high school students do not decide upon a career until they are well along in their high school education; some have not decided upon a career at the time of their graduation from high school. As a result, many students attempting to enter college or university engineering schools find themselves lacking necessary prerequisites for admission; in many cases, they are required to spend additional periods of time taking makeup courses before formal admission. To avoid this, it is essential that you choose a profes-

sion as early as possible and begin taking those courses which are prerequisites for admission into that professional program.

You should take as many courses as possible in the physical sciences and should also complete as much work in mathematics and the communication arts as your program will allow. While the exact requirements for admission to engineering schools in various universities will differ from school to school, these differences usually will be insignificant and, in general, the requirements will be as follows: a total of 15 or more standard high school units of credit, of which 12 must be academic, not vocational, in character. The distribution of these 12 units should be as follows: English, 4 units; algebra, 2 units; plain geometry, 1 unit; advanced mathematics (trigonometry, introduction to analytic geometry, calculus or equivalent), 1 unit; chemistry, 1 unit; physics, 1 unit; the remainder may be in history, social studies, or foreign languages. Some basic knowledge of mechanical drawing also is recommended. If possible, other physical science courses also should be included in the high school program.

In addition to carefully planning your high school program, you should prepare for a career in engineering in other ways. For example, develop interest in hobbies or crafts associated with technical activities. It is not necessary to be highly skilled in manual arts, but you might seek to develop some degree of manual and mechanical skill, since at sometime you will be expected to use instruments, tools, and equipment in whatever area of engineering you enter. Joining a student association or a club devoted to a technical hobby also can be extremely useful in indicating abilities and interest in technical areas. Participation in such activities offers an informal education which will be very valuable when considering a technical career.

It also is important to acquire good study habits during high school. Engineering students often find themselves pressed for time to complete all of their assignments and to keep current with all of their studies. Good study habits acquired during high school (particularly budgeting of study and leisure time) will pay dividends many times over in college and later in professional life.

CHOOSING A COLLEGE OR UNIVERSITY

Once you have decided upon a career in engineering, the next important decision you face is choosing which college or university to attend. Later in this chapter, the various types of engineering education programs will be explained in detail. The primary objective of this section is to assist you in evaluating universities and their engineering schools.

Basically, there are four major points to consider choosing a college or university. These include the university's faculty, its physical plant and facilities, its students, and its curriculum. All of these factors are important in creating a good environment in which students may be adequately prepared for future practice in the profession. The faculty must be well-rounded and diversified in their backgrounds and educational experiences if they are to give undergraduate students the best preparation for the engineering profession. In evaluating a university's faculty, look at the number and type of advanced degrees faculty members hold; in particular, consider the schools from which these degrees were obtained. In general, a university faculty holding advanced degrees from a large number of outstanding schools will provide an excellent learning environment. Adequate physical plant and facilities are also necessary, particularly today, when engineering laboratories must be equipped with the most sophisticated equipment and apparatus. Of course, other physical plant facilities also are necessary for a well-rounded education. The university should have adequate facilities for extracurricular activities, dining facilities, and, if necessary, facilities for the students to live on campus.

Another important feature of the educational environment is the student body itself. In general, a student body with diverse backgrounds, both geographic and economic, and with a reasonable number of international students will provide an opportunity for a broader educational experience than will a student body whose members are from the same geographic area or who come from very similar economic backgrounds.

Of course, one of the most important factors to consider is the engineering curriculum available at the particular school. With the

literal explosion of engineering knowledge and the rapid pace of technological advancement in civil engineering today, it is no longer possible for any curriculum to offer all things to all people who wish to enter civil engineering. In the curriculum of every school, it is necessary to specialize in one or several of the areas of practice in the field of civil engineering. These areas are explained in detail in Chapter 3. However, every school requires its students to complete a minimum core of courses which define the civil engineering curriculum. Generally, this core consists of approximately 30 percent of the student's study program. The remainder of the curriculum usually is divided among the humanities, engineering, and science courses of the areas of specialization. Look carefully at a school's curriculum to determine if the areas of civil engineering specialization it offers include the one that interests you as a future career.

All of the above mentioned items must be considered carefully and evaluated before an application for admission is made to a particular school. After you have selected one or more colleges in which you may be interested, the next step is to obtain information regarding the schools' specific programs and the requirements for admission. Almost all accredited colleges will require a transcript of high school courses and grades and will also require that college entrance examination scores be submitted. Most of the schools will accept either the American College Test (ACT) or the Scholastic Aptitude Test (SAT) as an indicator of academic capabilities. In addition, some colleges may require letters of recommendation, additional entrance examinations, medical examinations, and perhaps an interview with an admission officer. It is best to get the specific admission requirements directly from the college or university in which you are interested. It is very easy to obtain such information by writing to the admissions office of the institution under consideration and requesting a catalog, an admissions application, and copies of any brochures that the school may have which explain its civil engineering program. Do not put off obtaining such information until your senior year in high school. As previously pointed out, it may be necessary to assemble a number of different materials and to take specific examinations given in various localities only at certain times during the year. In addition, there may be a time delay in obtaining

letters of recommendation necessary to support the entrance application. Consequently, it is a good idea to begin to investigate the admission requirements of various colleges as early as possible.

For those who are already enrolled in a college program, it is usually possible to transfer to a program in civil engineering. In many cases, it is also possible to transfer credits earned during previous college work. In general, each school has its own particular policy on the transfer of credits from one program to another, and you should contact the admissions officer or registrar of the school you wish to attend to determine its specific procedure.

As a final note, it cannot be over-emphasized that in the selection of a career and a college, you can never have too much information. It is wise to discuss any school which is under consideration with alumni from that school. These people will be able to offer valuable information that you will not find in any of the school's publications. If possible, you should also discuss a college or university with one or more students who are currently attending that school. The professional reputation of any civil engineering school also may be discussed with practicing engineers, and their opinions should be considered along with all of the other available information before you make the final decision.

Finally, there are two types of college guide books. There are some which list the discipline, major, and characteristics desired by a student, then identify the schools which fit into that category. A second type of guide book provides extensive information about a particular school. The first type provides a good, systematic overview of schools; the second provides more comprehensive and detailed information about individual institutions. Four-year colleges guides include: *Lovejoy's College Guide*, *The New York Times Guide to College Selection*, *Profiles of American Colleges* (Barron's Educational Series), *The College Entrance Viewdeck* (Chronicle Guidance Publications). For two-year colleges see: *Guide to Two-Year Colleges* (Barron's Educational Series).

Each of these has a good "how to use it" section. Systematic individual research will provide an ample list of schools about which information can be obtained using the second type of information resource. Some sources giving more detail about the college are: *The*

College Handbook (The College Entrance Exam. Bd.), *Comparative Guide to American Colleges* (James Cass and Max Burnbaum). For two-year colleges see: *Comparative Guide to Two-Year Colleges and Four-Year Specialized Schools and Programs* (James Cass and Max Burnbaum), *Students' Guide to the Two-Year College* (Richard C. Richardson).

These guides may often be a year or more out of date. College catalogs should be studied for specific, official, and up-to-date information. Catalogs are available from the colleges or from the high school's guidance center.

CURRICULA

In order to meet the needs of a variety of students desiring to enter civil engineering practice at the end of a bachelor's degree program, or to continue working toward an advanced degree, undergraduate civil engineering curricula have been designed in many cases to give the individual student a great deal of flexibility. After a core of civil engineering subjects, common to all undergraduate programs, he can choose to concentrate a substantial block of his undergraduate programs in one or more of the specialty areas described in Chapter 3 of this text. Or, if such concentration is deemed not to be consistent with his career plans, the student may instead elect a more traditional program consisting of additional course work in each of the several civil engineering areas already introduced in the core of required subjects.

There are almost as many varieties of civil engineering programs available to the prospective student to choose from as there are civil engineering schools. Some of the curricula will involve little choice on the part of the student; some will involve much selection and choice. At some schools, all civil engineering students will study identical curricula, while at others there will be one or more options available for specialization. At some schools, the entire college period will be spent in academic work, while other schools will mesh academic experience with professional work experience, known as cooperative work. Recognizing that this variety makes the choice of

a university or college more difficult, the following articles have been arranged to give examples of a few of the types of curricula that are available at the present time. All of these are ECPD-accredited curriculum and thus could be considered good civil engineering programs.

BACHELOR'S DEGREE PROGRAMS

Traditionally, the formal education of the civil engineer has been the four-year program, relatively inflexible, leading to the bachelor's degree. By far the vast majority of engineering schools in the United States today still retain this format for their first accredited degree. The basic course requirements of most of these schools are usually quite similar. The curriculum usually consists of approximately one-quarter mathematics, physics, and chemistry; one-quarter English, humanities, and social sciences; one-quarter engineering theory; one-quarter analysis and design. The specific courses are selected to fulfill the requirements of the accreditation agency (ECPD), previously mentioned. Each curriculum will have minor differences in some of the courses required, as well as in the number of electives that the student is permitted to choose. However, the electives will not be numerous and the required courses usually will differ only in the depth of study into one or more of the civil engineering specialized areas. Typical of this type of program are those shown below.

BACHELOR OF CIVIL ENGINEERING

(University of Dayton)

First Year (Common Engineering Core)

Fortran for Engineers
General Chemistry
Mechanics I
Introduction to Engineering
College Composition I
Analytical Geometry and Calculus

Engineering Design Graphics
Introduction to Philosophy
General Physics I
Hum/Social Science Elective

Second Year

Surveying Field Practice (3 weeks—summer)

Third Semester

Surveying I
Seminar
Strength of Materials
College Composition II
Analytic Geometry and Calculus III
General Physics

Fourth Semester

Surveying II
Civil Engineering Laboratory
Seminar
Dynamics
Engineering Geology
Applied Differential Equations
General Physics
Engineering Graphics II

Fifth Semester

General Chemistry
Hydraulics
Seminar
Advanced Strength of Materials
Humanistic/Social Studies Elective
Philosophy Elective

Sixth Semester

Soil Mechanics
Theory of Structures
Seminar
Free Elective
Humanistic/Social Studies Elective
Religious Studies or Humanistic Elective

Seventh Semester

Highway Engineering
Seminar
Structural Design I
Reinforced Concrete
Sanitary Engineering
Technical Elective

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Eighth Semester

- Indeterminate Structures
- Seminar
- Structural Design
- Sanitary Engineering
- Technical Elective
- Religious Studies or Humanistic Elective

BACHELOR OF CIVIL ENGINEERING

(University of Virginia)

First Semester

- Introductory Calculus
- General Chemistry
- Computations in Engineering
- Language Communications and the Technological Society I

Second Semester

- Mathematical Analysis I
- General Physics I
- Graphics I
- Engineering Minicourse (Special Topics)
- General Education Elective

Third Semester

- Mathematical Analysis II
- General Physics II
- Solid Mechanics I
- Core Course
- General Education Elective

Fourth Semester

- Mathematical Analysis III
- General Physics III
- Solid Mechanics II
- Core Course
- General Education Elective

Fifth Semester

- Structural Theory I
- Fluid Mechanics
- Fluid Mechanics Laboratory
- Engineering Systems Analysis
- **Civil Engineering Elective
- General Education Elective

****Civil Engineering Elective Must be Selected from the list below**

Properties and Behavior of Materials
Structural Theory II
Design of Concrete Structures
Design of Metal Structures
Foundation Engineering
Water Pollution Abatement
Construction Engineering and Economics
Urban Transportation

Sixth Semester

Soil Mechanics
Environmental Engineering
Water Quality Laboratory
Transportation Engineering
****Civil Engineering Elective**
General Education Elective

Seventh Semester

Synthesis and Planning I
****Civil Engineering Elective**
*****Technical Elective**
The Engineer in Society
General Education Elective

Eighth Semester

Synthesis and Planning
****Civil Engineering Elective**
*****Technical Elective**
Western Technology and Culture

*****Technical Electives** may be selected from courses in the Department of Civil Engineering or in the School of Applied Sciences; or from other approved courses outside of the School. Normally, an elective program will include at least one design course.

OPTIONS WITHIN BASIC PROGRAM

In view of the many areas of specialization possible within the broad field of civil engineering, many schools offer the student optional tracks of study leading to the Bachelor's Degree. In contrast to the curricula in the previous section in which a limited number of electives is allowed, the following curricula have two or more course sequences to give in-depth coverage to an area of specialization. Among the areas of study that can be found at many colleges and universities in this country are those of water resources engi-

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neering, structural engineering, transportation engineering, public works engineering, construction engineering, geotechnical engineering, etc. All of these areas of study are described in more detail in Chapter 3.

Several programs of this type are shown on the following pages:

BACHELOR OF CIVIL ENGINEERING

(North Carolina State University)

Typical Freshman Year in All Engineering Curricula

- General Chemistry I
- Chemistry-Principles and Applications
- Engineering Graphics I
- Engineering Concepts
- Composition and Reading
- Humanities-Social Science
- Analytic Geometry and Calculus I

CIVIL ENGINEERING CURRICULUM

Sophomore Year

Fall Semester

- Introduction to Civil Engineering
- Introduction to Mechanics
- Analytic Geometry and Calculus III
- General Physics
- Humanities and Social Science
- Physical Education

Spring Semester

- Physical Geology
- Mechanical Properties of Structural Materials
- Mechanics of Solids
- Applied Differential Equation I
- Humanities and Social Science
- Free Elective
- Physical Education

Junior Year

Fall Semester

Engineering Surveying
Structural Analysis
Materials of Construction
Hydraulics
Engineering Project Analysis

Spring Semester

Transportation Engineering I
Structural Engineering I
Soils Engineering I
Water Resources Engineering I

Senior Year

Fall Semester

CE Electives**
Engineering Science Electives ***
Free Elective
Humanities and Social Science

Spring Semester

Civil Engineering Design
CE Elective
Free Elective
Humanities and Social Science

****Two Courses selected from:**

CE 406 Transportation Engineering II
CE 427 Structural Engineering II
CE 443 Soils Engineering II
CE 484 Water Resources Engineering II

*****Thermodynamics, Engineering Science and Mechanics, Electrical Engineering or Materials Engineering**

CONSTRUCTION OPTION CURRICULUM

Sophomore Year

Fall Semester

Introduction to Civil Engineering
Analytic Geometry and Calculus III
General Physics
Introduction to Mechanics
Humanities and Social Science
Physical Education

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Spring Semester

- Physical Geology
- Physical Geology Laboratory
- Mechanical Properties of Structural Materials
- Mechanics of Solids
- Applied Differential Equations
- Humanities and Social Science
- Free Elective
- Physical Education

Junior Year

Fall Semester

- Engineering Surveying
- Structural Analysis
- Materials of Construction
- Hydraulics
- Engineering Economics Analysis

Spring Semester

- Transportation Engineering I or Water Resources Engineering
- Structural Engineering I
- Soils Engineering I
- Construction Engineering I

Senior Year

Fall Semester

- Cost Analysis and Control
- Construction Engineering II
- Engineering Science Elective*
- Free Elective
- Humanities and Social Science

Spring Semester

- Construction Engineering Project
- Legal Aspects of Contracting
- Free Elective
- Humanities and Social Science

*Humanities and Social Science courses to be selected from standard school patterns.

**Thermodynamics, Engineering Science and Mechanics, Electrical Engineering, or Materials Engineering.

PROFESSIONAL STUDY IN CIVIL ENGINEERING

Fifth-year programs of study leading to professional degree of civil

engineer are offered in: sanitary engineering, soil mechanics and foundation engineering, structural engineering and transportation engineering.

BACHELOR OF CIVIL ENGINEERING

(University of Detroit)

All Options

Freshman Year

First Term

- General Chemistry I
- General Chemistry Lab I
- Analytical Geometry and Calculus I
- Graphical Communication
- Academic Writing
- Humanities and Social Science

Second Term

- General Chemistry II
- General Chemistry Lab II
- Analytical Geometry and Calculus II
- General Physics I
- Design Concepts
- Humanities and Social Science

Sophomore Year

First Term

- Analytic Geometry and Calculus III
- General Physics II
- Digital Computation and Simulation
- Humanities and Social Science

Second Term

- Differential Equations
- Modern Physics
- Statics and Stresses
- Digital Computation and Simulation
- Humanities and Social Science

Civil engineering at the University offers work in surveying, structures, soil mechanics and foundations, water supply and sanitary engineering, transportation, urban planning, hydraulics engineering, etc. The two options available within the department enable the student to concentrate either in structures and foundations or in urban planning and environmental engineering.

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In addition to the core program outlined above, civil engineering majors are required to take the following courses:

- Engineering Surveys
- Theory of Structures I
- Structural Design I
- Soil Mechanics
- Dynamics
- Mechanics of Deformable Bodies I
- Introduction to Systems Engineering

Those opting for Structures and Foundations are additionally required to take:

- Theory of Structures II
- Foundation Engineering
- Structural Design II

Whereas those opting for Urban Planning and Environmental Engineering are required to take the following:

- Transportation Engineering
- Water Supply and Sanitary Engineering
- Urban Planning

UPPER DIVISION CURRICULUM

Junior Year

First Term

- Mechanics of Deformable Bodies I
- Thermodynamics I
- Network Theory I
- Humanities and Social Science and/or Technical Electives

Second Term

- Theory of Structures I
- Dynamics
- Science of Materials I
- Humanities and Social Services and/or Technical Electives

Pre-Senior Year

First Term

- Introduction to Systems Engineering
- Fluid Mechanics
- Structural Design I
- Design I
- Humanities and Social Sciences and/or Technical Electives

Senior Year

First Term (Structures and Foundations Option)

Design

Theory of Structures II

Soil Mechanics

Humanities and Social Science and/or Technical Electives

First Term (Urban Planning and Environmental Engineering Option)

Design

Urban Planning

Soil Mechanics

Humanities and Social Science and/or Technical Electives

Second Term (Structures and Foundations Option)

Structural Design II

Foundation Engineering

Humanities and Social Science and/or Technical Electives

Second Term (Urban Planning and Environmental Engineering Option)

Water Supply and Sanitary Engineering

Transportation Engineering

Humanities and Social Science and/or Technical Electives

ADVANCED STUDY IN CIVIL ENGINEERING

It has long been recognized that the bachelor's degree does not fully prepare a college graduate for a lifetime practice in a profession. In all professions (law, medicine, engineering, etc.) additional study, formal and informal, is necessary to maintain competence in the light of continued technological change and professional growth.

In the field of civil engineering, this need is being met by three types of advanced study. The least formal type is that of continuing education (seminars, short courses, etc.) which is discussed in more depth later in this chapter. The other two types are the traditional graduate studies toward advanced degrees such as the master of science (M.S.) and doctor of philosophy (Ph.D.) degree, and the professional school, with study directed toward the master of engineering (M.Eng.) degree.

In the decade of the sixties, the American Society for Engineering Education commissioned a study by a group of distinguished educators and engineers to define "... the goals of Engineering Education" in our rapidly changing society and technology. In its final report,

issued in January 1968, this committee recommended more official recognition of the role of graduate study, especially the master's degree program, in the profession. There were, and still are, many critics of the final report; yet the faculties in a group of schools (maintaining that four years were inadequate for professional engineering education) adapted or revised their programs to include an undesignated B.S. degree after four years of study, with a professional master's degree (M.Eng.) being awarded after the fifth year of study.

Examples of programs such as these are shown on the following pages:

MASTER OF ENGINEERING DEGREE PROGRAM

(University of Louisville)

First Year

Fall Term

Introduction to Engineering I
Introduction to Engineering II
General Chemistry I
General Chemistry Lab I
Math Analysis I
English Composition I
Humanities and Social Science Elective

Spring Term

Introduction to Engineering III
Introduction to Engineering IV
General Chemistry II
General Chemistry Lab II
Math Analysis II
English Composition II
Mechanics I—Statics

Second Year

Summer Term

Mechanics II—Dynamics
Thermodynamics I
Math Analysis III

Fall Term

Electromagnetic Phenomena
Mechanics III—Mechanics of Solids
C. E. Field Measurements
Differential Equations I
Humanities and Social Science Elective

Spring Term

Active and Passive Networks
Mechanics of Materials
Mechanics of Materials Lab
Elementary Structural Analysis
Numerical Calculus
Humanities and Social Science Electives

Third Year

Summer Term

Cooperative Work Period No. 1

Fall Term

Fundamentals of Structural Design
Water Resources Engineering
Basic Science Elective
Physical Geology
Humanities and Social Science Electives
Free Electives

Spring Term

Cooperative Work Period No. 2

Fourth Year

Summer Term

Geomechanics
Engineering Hydraulics
Indeterminate Structural Analysis

Fall Term

Cooperative Work Period No. 3

Spring Term

Fundamentals of Concrete Design
Current Topics in CE
Free Electives
Humanities and Social Science Electives
Program Course I
Computer Methods in CE

Bachelor of Science awarded at this point.

Fifth year

Summer Term

Engineering Design Economics
Engineering Project
Program Course II
Urban Planning

Fall Term

Transportation Engineering
Master of Engineering Project
Basic Science Elective
Program Course III
Program Course IV

Spring Term

Master of Engineering Project
Humanities and Social Science Electives
Program Course V
Program Course VI

Another type of Professional Degree program is that of Rice University, as explained in that University's Bulletin:

A professional degree in civil engineering is available to a student after either a four-year or five-year program of study. A student may elect to take a four-year course of study leading to the degree of Bachelor of Science in Civil Engineering. Alternatively, a student may elect to take a five-year course of study leading to a Bachelor of Arts degree with a civil engineering major at the end of four years and a Master of Civil Engineering degree at the end of five years. Either the Bachelor of Science in Civil Engineering or the Master of Civil Engineering may be a terminal degree for those students interested in seeking a professional career after receiving the professional degree. A student interested in specializing in a particular area of the profession or with a special interest in preparation for a career in teaching or in research and development may choose to enter the graduate program in civil engineering after receiving the professional degree. It is also possible upon recommendation of the department and approval of the graduate council for a student to enter a program leading to the Master of

Program Elective Courses

Program Elective	Option I Structures	Option II Geomechanics	Option III Water Resources/ Hydraulics
I	Foundation Engineering	Foundation Engineering	Bio-organic Chemistry
II	Interaction of Soils & Struct.	Interaction of Soils & Struct.	Fluid Mechanics
III	Finite Elem. Methods in Struct. Analy.	Finite Elem. Methods in Struct. Analy.	
IV	Structural Dynamics	*Earth Pressures & Ret. Struct. *Groundwater & Seepage	Earth Pressure & Ret. Struct. Groundwater & Seepage
V	Matrix Methods in Structural Analysis	Rock Mechanics	Water & Wastewater or Surface Water Hydrology
VI	Hyper-Elastic Analysis of Structures	Hyper-Elastic Analysis of Structures	Industrial Processes and Waste Treatment

*Alternate years only

Master of Engineering Degree awarded at this point.

Science degree directly after completing the requirements for the Bachelor of Arts degree with a civil engineering major.

Preceptorship Program. A limited number of preceptorships are available on a competitive basis for civil engineering majors. After the fourth year of civil engineering study, a student will work for one year in the office of and under the personal guidance of a civil engineer who has achieved national and international prominence in the profession. The student is enrolled at Rice during the year away from campus, and then returns to Rice for the fifth year of study. The program is designed to provide the student with an opportunity to

experience the professional practice of engineering at its highest contemporary level.

The last type of advanced study in civil engineering discussed here is that of traditional study toward the M.S. or Ph.D. degrees with the usual research-oriented program. The primary focus of these programs has been the preparation of students for work in research or in academically related activities. However, as Civil Engineering education becomes more professional in character, it becomes less compatible with the traditional research degrees of the sciences and begins to assume the characteristics of graduate professional studies in law and medicine.

Different schools have approached this problem in different ways; some have maintained the traditional degree programs while others operate dual programs, one with a professional orientation and the other with a research orientation.

In most cases, the master's degree program may be a broad, one-additional-year general civil engineering program, or it may consist of a more narrowly structured program in one of the many subdisciplines of civil engineering. Many schools require the submission of a research or practice oriented thesis for the M.S. degree, while others will permit the substitution of additional course work for the thesis. In general, most programs are quite flexible, allowing the student to select the required number of courses from a wide and diversified group of offerings, with each student program tailored to fit a specific need.

A question frequently asked of counselors or admissions officers is, "What kind of undergraduate grade standing does it take to get into graduate school?" Perhaps the best information available in this regard is that given by the American Society for Engineering Education in its "Manual of Graduate Study in Engineering" (1952), in which is stated:

To qualify for admission to study leading to a master's degree, a strong postgraduate university may require an applicant to have a standing in the upper quarter of his class, if the undergraduate school is considered rela-

tively weak. However, a graduate school of modest standards may admit a man from a strong undergraduate school if he stood in the upper three-quarters of his class. A master's degree usually requires a minimum of one academic year, although a year and a half or even two years may be required if the student must make up any deficiencies.

Candidates for doctoral degrees have rarely ranked below the upper quarter of their undergraduate classes, and probably ranked in the upper five or ten percent. A minimum of three years beyond the bachelor's degree is required for a doctor's degree, although the time typically is longer—from four to six years. One of the reasons for the longer time is that doctoral candidates usually work part-time as teaching assistants or research assistants. The usual engineering doctoral degree is the Doctor of Philosophy (Ph.D.), although some schools offer the Doctor of Engineering (D.Engr.), Doctor of Engineering Science (D.Engr.Sc.), or the Doctor of Science (Sc.D.).

Some schools require a thesis for the master's degree, and some do not, but a thesis is universally required for a doctor's degree. The doctoral thesis is expected to represent an original contribution to the literature, but the master's thesis more generally is expected to represent a contribution to the training of the candidate, rather than a contribution to knowledge.

For specific details on the graduate program at a particular school, the student should consult that school's graduate bulletin for the current year.

COOPERATIVE WORK PROGRAMS

Among the other unique educational programs available to a student wishing to study civil engineering are those which incorporate

practical work experience along with academic requirements. These programs are known as Cooperative Work Programs. They involve close liaison between the schools and industries or governmental agencies in which the work experience is obtained. Cooperative Work Programs offer the student several advantages, the most important of which is the opportunity to take a realistic look at the world of civil engineering practice. Such work experience allows a person to evaluate the opportunities for work in the profession and to select the position of greatest potential for his own capabilities within the broad spectrum of civil engineering before making a permanent career decision. This experience in actual engineering work, concurrent with academic study, makes the co-op graduate a more valuable employee, allowing him or her to command a higher starting salary when seeking employment. Finally, the salary earned while on cooperative work assists the student in meeting college expenses.

There are essentially two types of academic programs which incorporate the cooperative work experience. The first type is a program in which co-op is a compulsory requirement for the degree, for all students. The master of engineering program shown in the previous section is an example of this type. The second type is the Bachelor's Degree Program in which co-op is optional, sometimes restricted to the better student, but resulting in a lengthening of the overall program, usually to a five-year bachelor's degree program.

BACHELOR OF SCIENCE (COOPERATIVE OPTION)

(Pennsylvania State University)

Cooperative Program—A five-year work study program in civil engineering is available to qualified students. Alternating periods of study and employment, a student may obtain a B.S. degree in five years instead of the usual four. Co-op students acquire two years of valuable engineering experience and also earn money to offset educational costs. Students are admitted to this program only after obtaining acceptance by the University and by a cooperating industry or government agency. Details regarding student selection and cooperating industries may be obtained from the department.

First Term

Chemical Principles
Experimental Chemistry
Engineering Orientation
Elementary Calculus with Analytical Geometry I
Elective (Approved)
Physical Education

Second Term

Introduction Engineering Graphics
Composition and Rhetoric
Elementary Calculus with Analytical Geometry II
Physical Education
Science Elective

Third Term

Engineering Design Graphics
The Writing of Ideas
Intermediate Calculus with Applications I
General Physics

Fourth Term

Structure and Function of Organisms
Statics
Differential Equations
Effective Speech
Physical Education 5

Fifth Term

Strength of Materials
Matrices and Statistics
General Physics
Health Sciences or Nutrition Elective

Sixth Term

Principles of Economics
Introduction to Algorithmic Processes
Dynamics
General Physics

Seventh Term

Engineering Surveying
Transportation Engineering
Structural Analysis
Electrical Circuits and Machinery

Eighth Term

Design of Concrete Structures
Water Pollution Control
Mechanical Response of Engineering Materials
Experimental Determination of Mechanical Response of Materials
*Social-Humanistic Elective

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Ninth Term

- Soils Engineering
- Fluid Mechanics
- Design of Steel Structures
- Physical Geology for Engineers

Tenth Term

- Concrete and Bituminous Materials Laboratory
- Engineering Hydrology
- Photogrammetry and Photo Interpretation
- Foundation Engineering
- *Social-Humanistic Elective
- Engineering Lecture

Eleventh Term

- Optimization Methods in Civil Engineering
- Hydraulic Engineering
- Civil Engineering Elective
- Technical Writing
- *Social-Humanistic Elective
- Engineering Lecture

Twelfth Term

- Engineering Law and Economy
- Geometrics of Transportation Ways
- Fluid Mechanics Laboratory
- Water and Wastewater Transport Systems
- Civil Engineering Elective
- Engineering Thermodynamics

*The 18 credits of Social-Humanistics Electives must be selected from the approved list of the College.

TRANSFERRING TO OTHER PROFESSIONAL SCHOOLS

Engineering has been defined previously as the application of mathematics and the natural sciences to utilize the materials and forces of nature, economically for the benefit of mankind. Thus, engineering education must, of necessity, deal not only with mathematics and the natural sciences but also with economics and the social sciences, since the engineer's work involves close relationships with people in their everyday living. The engineer is trained to ferret out all of the facts, assemble the complete data, including his own experiences, and only then to reach a conclusion or solution to a given problem. All of this must be done in a very logical and sys-

tematic way. To do this, he is trained to be constantly aware of the impacts of his work on his fellow men and upon the community.

This logical and systematized training has been found to be quite helpful in the study of many other professions, such as law, medicine, business, etc. Consequently, many students find it very effective to take their undergraduate training in civil engineering and then later to transfer to one of the other professional schools.

Many engineering schools, recognizing this possibility, have tailored special options within their curricula to accommodate this type of student. The most urgent requirement in this respect is for the student to recognize sufficiently early in his studies that he desires a program that will equip him for graduate work in a profession other than engineering. An early consultation with the academic advisor is a must in this regard, and will save a student much unnecessary time in an undergraduate program if he patterns his studies toward his goal as early as possible.

The program shown on the next page is structured to permit a degree in business, or a premedical option while studying undergraduate civil engineering.

BACHELOR OF SCIENCE (CIVIL ENGINEERING)

(University of Colorado)

A five-year program has been arranged for those students who wish to pursue the combined curriculum for the civil engineering and business degrees. A premedical option is available. A student interested in this option should consult with an adviser and the department chairman at the earliest possible time in order to make proper plans for an acceptable program.

CURRICULUM FOR B.S. (C.E.) (PREMEDICAL OPTION)

Freshman Year

Fall Semester

Intro. to Civil and Environmental Engineering
Calculus for Engineers I

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- General Physics
- Introduction to Computing
- Literature Elective

Spring Semester

- Calculus for Engineers II
- Fundamentals of Design I
- Literature Elective
- General Physics
- Experimental Physics

Sophomore Year

Fall Semester

- Analytical Mechanics I
- Plane Surveying
- Calculus for Engineers III
- Basic Science Elective
- Social Humanistic Elective

Spring Semester

- Mechanics of Materials
- Materials Testing Laboratory
- Technical Elective
- Introduction to Linear Algebra and Differential Equations
- General Chemistry
- Social-Humanistic Elective

Junior Year

Fall Semester

- Analytical Mechanics II
- Theoretical Fluid Mechanics
- Transportation Engineering
- Electrical Circuits I
- Engineering Science Elective
- Social-Humanistic Elective

Spring Semester

- Applied Fluid Mechanics
- Sanitary Engineering I
- Structural Analysis
- Soils and Foundations Engineering
- Thermodynamics
- Social-Humanistic Elective

Senior Year

Fall Semester

- Design of Steel Structures

Technical Electives
Geology for Engineers
Engineering Science Elective
Social-Humanistic Elective

Spring Semester

Reinforced Concrete Design
Senior Seminar
Technical Electives
Engineering Science Elective
Social-Humanistic Elective

GRADUATE WORK IN OTHER DISCIPLINES

In addition to the type of students mentioned in the previous section, who have as their educational objective the practice of a profession other than engineering, there also are many engineers who find graduate study in other disciplines to be helpful in their practice of engineering. In the same way that engineering training is found to be beneficial to other professionals, a knowledge of law or business may be necessary to an engineering consultant or to an engineer in an industrial management position.

Each year many thousands of graduate engineers enter law schools, master of business administration (MBA) programs, etc., and find that with a minimal amount of additional undergraduate work to obtain prerequisite courses for their graduate level course work, they have no difficulty in obtaining advanced degrees. Of course, as in all professions, these schools demand a certain level of excellence in undergraduate studies for admission into their graduate schools.

CONTINUING EDUCATION IN CIVIL ENGINEERING

Today, people in the western world are experiencing the most rapid technological and societal change, accompanied by what some have called a "knowledge explosion," that the world has ever known. It has been estimated that the amount of technical information avail-

able to the profession of engineering today has doubled since the end of World War II in 1946. In the face of this rapidly expanding technology, the civil engineer, as well as all other engineers, is required to continue his education after graduation if he is to maintain his ability to practice his profession. Upon graduation, the civil engineer should not only be knowledgeable about the present of the state-of-art, but should also have the capability to expand and improve his body of knowledge by keeping abreast of all the newer developments in his technology of engineering. This will demand a great amount of independent study, both formal and informal, on the part of the engineering graduate. The civil engineer must be familiar with the newer developments and materials available for use in civil engineering. Also, in many states, the engineering graduate is being called upon to periodically demonstrate that he is maintaining his competency and that he should continue to be licensed by the appropriate agency for the practice of engineering. It is necessary that the academic community take the lead in furnishing the engineer with viable programs that will allow him to acquire the necessary new knowledge to demonstrate current competency. Although the engineer has the prime responsibility for his personal professional development, universities and professional societies must also share this responsibility. Civil engineering schools must not only stress the necessity of continuing education but must also equip the student with the ability to assimilate this knowledge as a continuing educational experience.

A dramatic change has occurred in the period of time which elapses between a scientific discovery and its potential technological application. This time lapse formerly was on the order of several decades, whereas now it may be only a matter of months. The engineer's knowledge upon graduation, and his consequent worth are subject to rapid obsolescence as he engages in professional practice. In this respect, technological obsolescence can be thought of as existing when a professional person uses theories, concepts, materials, or techniques that are less effective in solving problems than others which are currently available in his field of specialization.

There are several ways by which a person may maintain current professional competence. The first is to enroll in one of the previous-

ly discussed formal educational programs leading to advanced degrees. Other ways of assimilating new technology are: on-the-job experience under the direction of another professional practitioner; or, continuing education studies either self-imposed or obtained through a more formal, organized educational program at a university. These continuing education studies at a university may be short courses, or one- or two-day seminars, with the specific objective of bringing the practitioner up-to-date with respect to a particular area of civil engineering, rather than directing a participant toward an additional academic degree.

Many industrial employers will arrange for continuing education programs to be held for their professional people. In such cases, many firms will pay full tuition or share the tuition cost with the participant for continuing education programs that will benefit and enhance the performance of the engineer in his duties for the firm. In still other cases, professional societies will sponsor meetings ranging in length from one day to as long as a week, in which technical papers are presented with the objective of bringing new information to the practicing engineer in as short a period of time as possible. The student entering an academic program leading to a degree in civil engineering should realize that, essentially, his education will never be complete, but will continue at intervals throughout his entire professional lifetime. The graduate engineer must survey the professional journals and magazines for notices concerning the time, scheduling, and cost for continuing educational activities. In this respect, it is important to point out that not all continuing education will be in the field of civil engineering with the intention of improving professional competence; much of the continuing education may be taken to improve the management skills of a professional employee. Many industrial firms finance or conduct special courses in interpersonal relationships, communication skills, and other managerial activities to improve the efficiency and effectiveness of their employees.

EDUCATION COSTS

In considering a career in civil engineering, a student will soon realize that the four or five years of required education will be time lost from gainful employment. This education will represent not only a definite cost in terms of wages lost, but also in terms of the direct costs associated with college life.

According to several studies conducted by academic associations and other groups, tuition, fees, room and board, and other expenses at a private four-year college currently amount to over \$5,000 per year. The same expenses at public institutions amount to approximately \$3,500. In contrast to these costs, it has been estimated that attendance at a private two-year institute or college costs approximately \$4,000 per year, while attendance at public two-year colleges costs approximately \$2,500 per year.

These are estimated average costs for tuition, room and board, and fees in colleges and universities offering programs in engineering. However, the costs associated with attending a particular university or college can vary quite widely from these averages, and it is important to investigate the costs of the particular school you wish to attend. One very significant consideration is the difference in tuition rates and other fees for residents and non-residents of states in which certain schools are located. Significantly higher tuition rates are charged to non-residents by most state schools.

Although tuition may vary significantly from one institution to another, expenses for room and board, books, and supplies can be reasonably estimated. On the average, room and board at a technical institute or college offering an engineering program should cost between \$2,000 and \$2,500 per year. Books and supplies will cost an additional \$300 to \$350 per year. These costs may vary somewhat from one institution to another, but they represent typical average expenses.

FINANCIAL AID OPPORTUNITIES

Since costs for any college education are significant, it is important

to investigate all possible sources for financial aid. Many eligible students may receive aid from the Veterans Administration or from the U.S. Department of Health, Education, and Welfare. Additionally, scholarships and loans are available from various organizations and from individual schools and colleges. Finally, many social and professional organizations offer scholarships and loans for students who are in some way connected with members of these groups.

In many instances, the benefits available to veterans also can be applied to their dependents. Information concerning all of the educational benefits available to veterans can be obtained by contacting a local Veterans Administration office. Assistance is available through the Red Cross for veterans who are unable to contact representatives of the Veterans Administration.

Department of Health, Education, and Welfare

The Department of Health, Education, and Welfare makes available considerable financial assistance to college students. This assistance is furnished under a number of different programs. In the Supplemental Educational Opportunity Grant Program, students with exceptional financial needs, who are unable to continue their education without assistance, are eligible for awards of not less than \$200 and not more than \$1,500 per year. Students must be enrolled in an approved institution for at least a half-time program. The awards may be received for up to four years in general education programs, but in cooperative programs or other professional schools with five-year programs, the awards may be extended over the full five-year period. However, no more than \$5,000 can be awarded to one individual during a five-year course.

The Basic Educational Opportunity Grant Program is another source of funds for eligible students. Full-time students of universities, community colleges, and junior colleges may apply for financial assistance under this program. Applications generally are available from high school counselors, from colleges, and from public libraries. Applications also may be obtained by writing to the Department of Health, Education, and Welfare, P.O. Box 84, Washington, D.C., 20044. If the student is judged to be eligible for assistance, notifica-

tion of eligibility is submitted to the college of the student's choice for a determination of the amount of the award. The amount of such an award is calculated by the college on the basis of the cost of tuition and the capabilities of the student and his family to meet such costs.

In addition to financial scholarship awards as described above, financial assistance also is available from the United States Government in the form of student loans. Under provisions of the National Direct Student Loan Program, students who are enrolled in a school at least half-time and are unable to fully meet their educational expenses may borrow as much as \$2,500 if they have completed less than two years leading to a bachelor's degree. If the student is an undergraduate who has already completed two years toward a Bachelor's degree, the loan may be increased to as much as \$5,000. Under provisions of this program, the student must begin repayment of the loan nine months after completing his course of study, either through graduation or through withdrawal for other reasons. If it is necessary to do so, the student may extend repayments over a ten-year period with an interest charge of 3 percent on the unpaid balance of the loan. If the student leaves college to enter the armed forces, the Peace Corps, or Vista, he need not repay any part of the loan for the first three years after termination of his course of study. Additionally, some loans under this program may require no repayment if the student enters certain fields after graduation. Information on the details of this program can be obtained from the financial officers in the colleges where civil engineering programs are offered.

Another program through which a student may obtain a loan to complete his studies is the Guaranteed Student Loan Program. Under provisions of this program, the student is allowed to borrow directly from a local bank, credit union, or savings and loan association. Repayment is guaranteed by state or private agencies, and the loans are insured by the federal government. To be eligible for such loans, students must be enrolled for at least a half-time program in an approved college or university. Where eligible, the student may obtain a loan of up to \$2,500 per year, but the maximum total amount which may be borrowed during the complete program of studies is \$7,500. Repayment generally must begin within about nine

months after graduation or termination of studies, and ten years are allowed for repayment of the total loan. Repayments are not required for up to three years if the student is serving in Vista, the Peace Corps, or the armed forces. Detailed information and applications for these loans are available from banks, schools, and regional offices of the Department of Health, Education, and Welfare.

Work-Study Programs

In addition to obtaining grants or loans, the student may obtain financial assistance through work-study programs financed by the federal government. The College Work-Study Program is funded by the Department of Health, Education, and Welfare for the purpose of providing jobs for students who have extreme financial needs. To be eligible, the student must be enrolled at least half-time in an approved education institution. A student's particular job assignment is arranged by the college, and he may work in campus laboratories, offices, libraries, and cafeterias. In some cases, a university or college may place a student in a position off-campus with a public or private non-profit organization such as another school or hospital. Students may be employed for as many as 40 hours per week; they must receive salaries equivalent to the current minimum wage. Information and applications for such assistance can be obtained from the financial officers of individual schools.

Other Sources

In addition to those listed above, there are many other sources of financial assistance available to prospective engineering students. Most colleges and universities have special scholarship programs and loan funds for students in selected programs. Additionally, there are funds for educational purposes available from other sources which often are overlooked. These include parents' employers, local clubs, fraternal organizations, veterans associations, youth groups, religious organizations, chambers of commerce, and other societies and organizations. Every effort should be made to explore these possible sources of assistance, and a student should seek guidance from his high school counselor and from financial aid officers at the

institutions he thinks he might like to attend. Many times, students fail to receive scholarships and other forms of financial assistance simply because they are unaware of the possibilities or because they apply too late.

Almost every university has a special Financial Aid Office with the responsibility of administering aid programs at that particular school. As soon as a prospective student has received notice of acceptance for admission to the school of his choice, he should contact the financial aid officer to determine what information and forms must be submitted before a request for financial assistance will be considered. Many universities will require the submission of the Parent's Confidential Statement, a statement of the student's own financial situation and in some instances the university's own Financial Aid application. These forms should be submitted at the earliest date possible.



Photo ASCE

John Roebling's Brooklyn Bridge, begun in 1867 and finished by his son in 1887. The Brooklyn Bridge has long been a familiar symbol of civil engineering achievement.

CHAPTER 3

SPECIALTIES WITHIN CIVIL ENGINEERING

In the first part of this book, the history and scope of the field of civil engineering were discussed. That description should have given you a broad spectrum of activities included in civil engineering. This spectrum is so great, in fact, that it is impossible to describe all of the activities of civil engineers in a book such as this. It also is very difficult to include a description of all the ways in which civil engineers work with other engineers, scientists, and non-technical personnel. However, some of the major technical specialties and some of the functional activities within the broad field of civil engineering can be described in more detail. For our purposes in this book, it is possible to group all of the activities of civil engineers into various technical categories, such as structural engineering, transportation engineering, environmental engineering, etc. The activities of civil engineers working in any one of these technical specialties also can be divided into several functions, such as research and development, planning and design, supervision of construction and operation, engineering sales, and management. The technical fields of specialization will be described first, followed by the different functional activities of civil engineers.

TECHNICAL SPECIALTIES

The American Society of Civil Engineers has established a number of technical divisions within its organization, and these divisions give good indication of the various technical specialties within the general field of civil engineering. They include Surveying and Map-

ping, Water Resources Planning and Management, Hydraulics, Irrigation and Drainage Waterways, Harbors and Coastal Engineering, Structural Division, Engineering Mechanics, Highways, Air Transport, Pipeline, Urban Planning and Development, Urban Transportation, Construction, Geotechnical Engineering, Environmental Engineering, and Power Divisions. The ASCE also has Technical Councils on other specialty areas including aerospace engineering, computer practices in civil engineering, earthquake engineering, and ocean engineering. The work carried out by civil engineers in these various specialty groups can best be described by combining those activities which are most often closely associated in practice. Such combinations will be used in the description that follow.

Surveying and Mapping

The field of surveying and mapping is as ancient as historical records. Land surveys were conducted in ancient Babylonia and Egypt, more than 4,000 years ago. Surveying and mapping efforts also played a very important role in the development of the United States. These surveying expeditions included that of Lewis and Clark, who traveled up the Missouri River and then onto the Pacific Ocean in 1803, and the expeditions which led to the development of the American West in the 1850s and 1860s. A major new development in surveying and mapping occurred in the 1920s when airborne cameras were used to produce photographic maps. This type of mapping now has been carried to even greater sophistication through the use of the mapping satellites which now circle the globe.

One of the activities included in the general field of surveying and mapping is called cartography. Cartography includes all those activities in the field necessary to the development of maps, as well as those activities in the office associated with drawing, editing, and printing of the maps. Cartographers prepare maps and charts from data gathered by physical surveys, by aerial photography, and by the more sophisticated means of exploration, such as remote sensing using various forms of radar and other techniques. The products of cartographers include topographic maps showing the elevation and major physical features of the land surface; nautical and aeronautical

charts; meteorological maps; city maps; political maps of countries; atlases; and many other types. The most important ingredient in producing maps is the preservation of accuracy throughout the entire process. Precise surveying techniques are utilized and precision drafting instruments, aerial cameras, and printing machines are used. The cartographer develops maps from numerical and photographic data. In order to convert numerical and physical data into maps to be used by pilots, drivers, and pedestrians, the cartographer calls upon his education and experience in the general field of engineering and, particularly, his knowledge of geography and his skill as a designer and artist. In order to produce maps of various kinds, the cartographer depends upon information supplied by surveyors.

Land surveying is that branch of surveying concerned principally with the determination of boundaries of real property. Land surveying also includes the planning and subdivision of areas and the preparation of deed descriptions for conveying ownership of parcels of land. Obviously, the land surveyor must work closely with draftsmen and cartographers in the preparation of maps showing natural and man-made features on the land, the land and water surfaces in a given area, and the boundaries of pieces of property. The work of the land surveyor includes the establishment of state and local boundaries for the definition of townships, ranges, and sections. Land surveyors generally are persons in private practice who are registered in one or more states. Today, in the United States, there are approximately 30,000 land surveyors. The techniques utilized by the land surveyor are quite similar to those used in other engineering surveys.

Engineering surveys consist of those measurements which provide the data utilized by engineers in planning, locating, designing, and constructing physical facilities. Basic data for design may include the horizontal and vertical positions of natural features of the land surface, the location of man-made features, and the depiction of these conditions through the preparation of cross-sections and profiles which show the elevation and character of the ground surface along lines established for design or construction purposes. Engineering surveyors are responsible for the layout of structures to be built, the measurement of quantities of materials used in construction, and the

performance of surveys in mines and quarries.

In recent years, land surveyors and engineering surveyors have come to depend more and more on aerial photography as an important aid in surveying and mapping. In such work, cameras are installed in specially designed aircraft which fly at predetermined altitudes along straight lines across the land area to be mapped. The flight paths of the aircraft are arranged so that the land areas photographed each time the camera shutter is opened will overlap. The product of the aerial survey is a series of photographs which can be placed in a definite sequence along lines which correspond to the flight paths. The height of the aircraft and the camera angle are adjusted so that the overlap of the photographs permits the cartographer to use optical devices to get a three-dimensional view of the land surface. Mechanical devices and instruments have been devised for use with aerial photographs so that topographic maps showing the elevation of the ground surface at any particular point can be prepared mechanically. This type of surveying has been greatly refined and now can be applied to the entire surface of the globe through the installation of cameras in satellites.

In addition to such optical devices as transits, levels, and theodolites, surveyors now use electronic computers to adapt the data obtained from surveying instruments for immediate use in the preparation of maps. All of these sophisticated devices and techniques are utilized to prepare maps of the surface of the earth, charts of the ocean bottom, boundary lines to private and public lands, etc. This branch of civil engineering is among the oldest of the specialty areas within civil engineering, but it accounts for only about four percent of the total number of civil engineers in the United States.

Water Resources Engineering

Water resources engineering includes the activities of civil engineers who are engaged in obtaining adequate supplies of drinking water and water for industrial uses; engineers who design and construct structures to retain and transport water; engineers who are concerned with the relationships between rainfall and the amount of water stored in the ground as well as that which flows across the land

surface; and engineers engaged in irrigation and drainage of agricultural lands. The general area of water resources engineering includes many engineers who are primarily concerned with maintaining water quality. These engineers work to purify drinking water supplies and to treat wastewaters so that they can be released into streams and other bodies of water. The activities of this last group of engineers will be described in a later paragraph on environmental engineering.

The most important activity of water resources engineers is the development and conservation of adequate supplies of water for drinking water needs and for use in industry. Water resources engineers also are engaged in supplying water for irrigation of farmland, particularly in the arid areas of the American Southwest. Supplying adequate quantities of water for today's industrialized society in America is a tremendous undertaking. Drinking water supplies are a major item; the average American uses between 150 and 200 gallons of water a day for drinking water, bathing, washing automobiles, water lawns, washing clothes, and for many other domestic uses. The water requirements of industry are much greater than the demands for domestic water supplies. For example, over 100,000 gallons of water are utilized in the manufacture and assembly of an automobile, and more than 80,000 gallons of water are utilized in making a ton of steel. On the other hand, the average water requirement for irrigation in the United States is more than one million gallons of water each year per acre of irrigated farmland. The job of ensuring reliable supplies of water for all these uses falls to civil engineers who are engaged in water resources engineering.

Water resources specialists may devote most of their time to studies in hydraulics or hydrology. Hydraulics is the study of the movement of water in response to applied forces and of the forces and pressures which are created by both moving and stationary bodies of water. Hydrology, on the other hand, is the study of the occurrence of water in the atmosphere—the fall of water to earth as precipitation in various forms, the flow of water across the surface of the earth, and the infiltration of water through the surface of the earth to underground storage areas. Hydrologists work to determine the availability of water supplies for various uses; in other words,

they attempt to determine how much water can be used safely each year for particular purposes, without permanently depleting and exhausting the supply of available water.

In controlling the flow of water across the land surface and in storing surface water and groundwater in various locations, water resources engineers must construct dams, floodwalls, pumping stations, aqueducts, and canals. Dams are constructed to store water for irrigation supplies, for municipal supplies, and for the generation of electric power. In almost all cases, dams, pumping plants, and associated pipelines or aqueducts are designed to satisfy many separate purposes so that the most efficient overall use of the available waters is achieved. The designer of such water-retaining structures as dams and floodwalls works with irrigation and drainage specialists in designing and constructing canals and other facilities for carrying the water to areas where rainfall is deficient. More than 35 million acres of land are irrigated at the present time in the United States, principally in the Southwest. The work of irrigation and drainage engineers in the United States today is very similar to the work of the ancient Egyptian engineers mentioned in Chapter 1, who worked to distribute the flood waters of the Nile across their valley homeland.

Water resources engineering also includes the activities of those engineers who are concerned with the planning, design, and construction of facilities to allow navigation on waterways throughout the United States. Also included in the area of water resources engineering is the design and construction of floodwalls and levees to hold back maximum flows in rivers to prevent flooding. Flood control also can be achieved through the construction of reservoirs which retain rapid runoff and maximum stream flows, so that these quantities of water can be released gradually to prevent flooding downstream. Also included in the general area of water resources engineering is the planning and construction of harbor facilities along the nation's coastlines. Harbor engineering includes design and construction of artificial channels, canals, piers, and docks; dredging of navigation channels in harbors; and protection of shorelines from erosion by wind and wave action. All of these activities are included within the area of the civil engineering specialization which is called water resources engineering. More than one-fifth of

all the civil engineers in the United States are engaged in water resources engineering.

Structural Engineering

The field of specialization within civil engineering which produces perhaps the most dramatically visible products is that of structural engineering. Structural engineers are concerned with the planning, design, and construction of all types of physical facilities, especially bridges and buildings. Structural engineers do not actually build the bridges, skyscrapers, and factories, but they are responsible for the planning and design of these facilities. Structural engineers are concerned with the property of such materials as steel and concrete, and they are very interested in new developments in the production of these materials. For example, steel alloys are being produced now which provide much greater strength than was formerly attainable. These new, high-strength materials allow structural engineers to conquer space with beams, girders, and columns in ever more dramatic fashion, as well as conserve valuable raw materials for future generations.

Some structural engineers are concerned principally with the behavior of materials subjected to either static or dynamic loadings. These individuals often are found in universities and in research institutions, and they are likely to be members of the Engineering Mechanics Division of the American Society of Civil Engineers. The structural designer on the other hand, is concerned with using the materials developed by materials scientists and manufacturers to design and plan factories, warehouses, commercial buildings, power plants, and all of the other structures which can be found in the modern city. The principal problem faced by structural designers is the use of available materials in the most efficient way to satisfy the desires of clients, usually the owners of the proposed structure. Obviously, the structural designer must also suit his design to the conditions on a particular selected site. The finished structure must be capable of performing the desired function or purpose, whether it is located on a hillside or in a cypress swamp; in Florida or Alaska; in rain, wind, snow, earthquake, and all of the other extremes of weath-

er to which a structure may be exposed. One of the most important fields of activity for today's structural engineers is the design and planning of power plants and their associated structures, especially nuclear reactor containment facilities. The containment vessels used to house nuclear reactors obviously must satisfy very strict safety requirements for the protection of the public. The structural engineer also must be very careful in designing the foundations in power plants where coal is burned to produce steam; steam-powered turbine-generator units for the production of electricity are very sensitive to settlement.

Probably the most dramatic structures designed by civil engineers are bridges. Bridges come in a variety of forms and shapes including arch bridges, cantilever bridges, truss bridges, and—most dramatic of all—suspension bridges. The most outstanding examples of suspension bridges are the Golden Gate Bridge in San Francisco and the Verrazano Narrows Bridge between Staten Island and Brooklyn, in New York. These graceful structures, spanning thousands of feet from shoreline to shoreline, seem to leap from one bank to the other and are among the most graceful creations of civil engineers. At the same time, these beautiful structures, as well as all other types of bridges, must be designed to carry heavy traffic loads in all sorts of weather and must be capable of withstanding any natural forces produced by wind, tide, and earthquake. The bridge designer is faced with the problem of developing a structure at the lowest possible cost, without sacrificing any safety provisions or reducing the capacity of the structure in any way. To meet this challenge, structural engineers are being furnished with new materials of greater strength, more durability, and lower weight, by other engineers and scientists who are engaged in research and development activities. The work of the modern structural engineer requires a comprehensive knowledge of the properties of materials as well as a deep appreciation for the balancing of forces in complex, three-dimensional structural frameworks. Structural engineers are among the most numerous civil engineers in the United States today, accounting for more than 20 percent of the total number of civil engineers.

Transportation Engineering

The civil engineering specialists who are engaged in transportation engineering include railroad engineers, highway engineers, air transport and aerospace engineers, and pipeline engineers. The railroad engineer has given place in many localities to the highway engineer, since highways have now replaced railroads as the major carrier of persons and, to a great extent, freight in the United States today. Nevertheless, today more than 300,000 miles of railroad track remain in service in the United States. In order to meet the increasing costs of maintenance of track and roadways, railroad engineers are constantly engaged in rebuilding old railroad lines and improving the combined structure of the rail, tie, and the supporting ballast beneath the track. New lines must be built to serve new industrial and commercial facilities. In recent years, a combination of truck freight with railroad transportation is the "piggy back" service in which truck trailers are carried long distances on railroad flat cars. This has led to the demand for new terminal facilities designed to accommodate this new type of traffic. A large portion of the nation's raw materials, including many ores and fuels such as coal, still travel by rail, as do many types of manufactured goods (heavy industrial machinery, new automobiles, heavy military equipment, etc.). In urban areas, railroads are being redesigned to satisfy rapid transit needs. Urban rapid transit work includes the planning design of subways, elevated rail lines, and surface rapid transit routes. Railroad engineers' responsibilities in accomplishing all of these activities are quite similar to the work carried out by the highway engineers.

Highway engineers are responsible for the planning, design, and maintenance of highway systems and secondary roadways. Highway engineers' work begins with the planning of highway facilities to meet future needs created by changing population patterns and the growth of cities and towns. Their work, in this respect, is similar to that which was done by the railroad engineers during the development of railroad systems in the United States more than 100 years ago. Highway engineers must analyze basic traffic patterns and attempt to predict future traffic flows. After determining the need for highway facilities on the basis of traffic predictions, they must

develop the most economical combination of highway structure and location. Highway engineers are involved in the construction of embankments and fills to carry roadways across low areas with cutting through hills and mountain ranges. Highway pavements must be designed to reflect most efficient use of asphalt, concrete, and other materials, available at different prices in different locations. All of these factors—available materials, alternate routes, traffic demands—must be considered by the highway engineer in developing the most efficient transportation system for the lowest expenditure of money, materials, and labor.

A more specialized area of transportation engineering activity is the planning and design of airports and their related facilities. The most exotic activity of transportation engineers, in this regard, is the planning and design of space ports and other facilities associated with the exploration of space. However, such glamorous activities occupy the time of only a very few civil engineers. Many more are concerned with the design and construction of airport facilities, including hangers, runways, taxiways, parking aprons, and terminal facilities. These facilities must be adequate not only for the landing, movement, and takeoff of aircraft, but also for the handling of passengers, freight, and the equipment necessary for aircraft maintenance and service.

A not so obvious form of transportation engineering is the planning and design of pipelines to carry liquids, gases, and combinations of liquids and solids. The pipeline project most familiar to readers today probably would be that of the design and construction of the pipeline to bring petroleum from the North Slope of Alaska to consumers in the "lower 48" United States. However, many other pipeline projects of great importance have been planned and designed by civil engineers specializing in this area. Natural gas pipelines were constructed throughout the United States in the years following World War II to provide Americans with one of the most convenient forms of energy for use in space heating and industrial processing. It is also possible to move slurries (mixtures of solids and water) efficiently over long distances in pipelines. Pipeline transport of coal slurries is assuming increasing importance today as we are faced with possible shortages of natural gas and petroleum. Civil engineers who

specialize in pipeline transport of materials must determine the most economical alignment of the pipelines, with full consideration for the possible social, political, and environmental effects of such construction. They design and plan power plants, terminal facilities, receiving and discharge plants, and pumping stations associated with pipelines. Transportation engineers engage in pipeline work closely with structural engineers and with geotechnical engineers, other specialists in the broad field of civil engineering.

Public Works/Urban Planning

More than three-fourths of the population of the United States lives in cities. Consequently, much of the work of the civil engineer today is associated with the design and planning of structures and facilities to serve urban communities. Civil engineers are engaged in the planning and development of cities working with other planners and designers in associated fields to accomplish a variety of tasks. The city planner predicts future needs of the community with respect to streets and roadways, recreational and park facilities, freeway and airport locations, urban renewal projects, industrial parks and associated developments, and residential areas. Civil engineers engaged in city planning may work as members of planning commissions or zoning boards which act in an advisory capacity to elected municipal officials. In many cases, the civil engineers' contributions as members of zoning commissions will be to provide the necessary technical expertise required for decisions on the control of community development in particular areas so that the overall growth of the community is balanced and coordinated. The engineers will work closely in these activities with planners, architects, politicians, citizen groups, and other persons concerned with the wise and careful planning of future urban development.

The day-to-day maintenance activities of cities and towns are the province of public works engineers, who generally are civil engineers employed by municipal or county government. They often act in a supervisory capacity and coordinate the efforts of consultants and other civil engineers who are working on the design and construction of specific projects. Public works engineers are responsible for the

coordination of activities associated with water supply systems; drinking water distribution lines; wastewater treatment and disposal systems; municipal streets, roadways and parking facilities; solid waste collection and disposal systems; schools, hospitals, libraries and other types of public buildings; and municipally owned service facilities such as power utilities. Public works engineers must be educated in a broad spectrum of civil engineering activities and must be capable of managing and coordinating the efforts of many other engineers and non-technical personnel.

Construction Engineering

Construction engineering is one of the newer specialties within the general field of civil engineering, even though construction supervision is a very old civil engineering activity. Construction engineers are educated in the general field of civil engineering, specializing in management and control of construction activities. They are vitally concerned with the planning and scheduling of every phase of construction activity on a particular project, from the initial order of materials from a supplier, to the day on which the owner takes possession of the finished structure. Construction engineers must plan the entire job, including deciding what equipment, materials, and labor will be needed at any particular location on any given day. They are heavily engaged in scheduling and programming activities. In most cases, construction engineers are employees of construction companies, or they are the owners of such companies. If they are new to this field of activity, they may be involved with testing the materials of construction and in inspecting the job to make sure that it complies with the designers' specifications. As construction engineers gain more experience, they are given responsibility for supervising construction activities, including the planning of various types of plants. With continued experience, they may assume management roles in construction companies. Experienced construction engineers will be responsible for hiring laborers and construction specialists, for estimating costs based upon structural designs, and for monitoring day-to-day expenses on the job site. Construction engineers must work closely with designers and with

the owners of the structures being built to ensure that the owners' wishes and desires are carried out in the most efficient way for the least amount of money.

Geotechnical Engineering

Another rapidly growing specialty group within the field of civil engineering is geotechnical engineering. Geotechnical engineers are responsible for determining the characteristics of the soils and rocks at a given construction site or along the route of a transportation facility. Geotechnical engineers apply the principles of mechanics to the natural soil and rock materials that are found on project sites. They develop designs for foundations to support bridges, industrial buildings, and other structures. They develop excavation techniques and construction methods for tunnels and other works. They are responsible for conducting exploration and testing of the geological materials which will be the foundations of the structures included in particular projects, or which will form the construction materials for embankments for highways and railroads, or for dams, levees, and floodwalls. Geotechnical engineers work closely with engineering geologists to detect possible weaknesses in the soils and rocks at particular sites, and with structural engineers and designers to match the characteristics of the designed structures to the limitations of the soils and rocks found at the site of the proposed facility.

Environmental Engineering

A new field of civil engineering specialization has arisen in recent years—environmental engineering. For many years, civil engineers were involved in obtaining and purifying drinking water supplies and in designing and planning facilities for the removal and treatment of wastewaters from residences and industrial facilities. This role of pollution control has been greatly expanded in recent years to include efforts directed toward air pollution control, solid waste management, and environmental impact analysis as well as the more traditional activities of water pollution control. Civil engineers engaged in this area of specialization work closely with ecologists,

biologists, and other scientists to determine the quality of life in particular environments. They try to develop engineering systems to accomplish particular goals with minimum damage to the natural environment. These pollution control activities include the design and planning of wastewater treatment facilities, flood control facilities, groundwater recharge areas, air pollution control facilities, and resource recovery plants. This specialty within the broad field of civil engineering is expanding rapidly.

Other Specialties

A number of other specialty areas of engineering attract limited numbers of civil engineers. Included in these are power plant design and construction; design and construction of power transmission lines; application of computer techniques in civil engineering problems; applications of systems science (optimization techniques) to the design and planning of public works facilities; and design and construction of ocean-floor and offshore structures, particularly structures associated with petroleum exploration, removal, and transport. Civil engineers find little difficulty in utilizing their basic education in the sciences and in accumulated civil engineering experience in particular areas of activity such as of those listed here. In all of these areas of specialization, they work closely with a number of engineers and scientists in closely affiliated specialties.

Engineering Geologist. Because civil engineers are responsible for the design and construction of facilities in and on the earth, they often work closely with geologists and geological engineers. Engineering geologists are concerned with the characteristics and formation of the materials in the earth's crust. They are interested in applying engineering principles, with their knowledge of geological properties, to predict the capability of the materials at a given site to serve as foundations for proposed structures, or as construction materials for embankments, dams, or other facilities. Engineering geologists must possess a strong background in soil and rock mechanics as well as geology. They work closely with civil engineers in designing and planning foundations, tunnels, dams, and other facilities, contributing their special knowledge of the characteristics

of earth materials to the solution of the overall engineering problem.

Industrial Engineers. Civil engineers also work closely with industrial engineers in the design and planning of structures for industrial and manufacturing plants. Industrial engineers are concerned principally with the optimum flow of material and power through a manufacturing process. They are interested in obtaining the most efficient use of raw materials with the least expenditure of energy and manpower to produce a finished item. Industrial engineers work closely with civil engineers in developing the most appropriate designs for structures to house manufacturing activities. They also develop scheduling and programming methods used in manufacturing and construction activities.

Mining Engineers. Civil engineers work closely with mining engineers in developing excavation techniques to obtain such raw materials as coal and mineral ores from deposits within the earth. They are interested in developing the most efficient and least expensive excavation techniques consistent with maintaining the safety of the miners on the job site and of the residents in the surrounding community.

Nuclear Engineers. In a similar way, civil engineers work with nuclear engineers in the design of structures to house nuclear power plants and to ensure that the continued operation of such facilities will proceed with the required degree of safety. In many cases, geologists, civil engineers, and nuclear engineers pool their talents in assessing the suitability of sites for nuclear power plants. One of the most serious problems associated with the construction and operation of nuclear power plants is the danger to such plants from earthquake tremors. Nuclear engineers rely on civil engineers and engineering geologists to assess such danger and to develop structures capable of withstanding such shocks.

Others. Civil engineers also work with many other engineering specialists—for example, with petroleum engineers in the development of petroleum extraction structures, offshore loading facilities and terminals, and storage and refining facilities on shore. Civil engineers work with biomedical engineers in the development of devices which apply technology to the assistance of handicapped persons and those undergoing medical treatment. In many instances,

civil engineers apply their basic knowledge of engineering sciences and their experience with physical systems to the analysis of the systems within the human body. They work closely with biomedical engineers and with physicians in developing operating techniques, methods of physical therapy, and devices used as replacements for damaged body parts. The interactions of civil engineers with other engineers, with scientists and with non-technical specialists are virtually innumerable. In accomplishing all of these specialized tasks, individuals exercise various capabilities and talents; in other words, civil engineers play many roles and carry out many different types of functions. Most of these functions can be grouped under the general categories of research and development, planning and design, field supervision, engineering sales, and management.

FUNCTIONAL SPECIALTIES

Many civil engineers are engaged in planning and design activities, and great numbers are involved in supervision of construction and operation of engineered facilities. However, a significant number of civil engineers also are engaged in research and development activities. Some individuals who have been educated and received their primary experience in civil engineering have moved into sales of equipment and systems designed to accomplish many of the purposes of these engineered facilities. Engineering sales requires certain characteristics, not the least of which is a very comprehensive and adequate background in engineering. Finally, some civil engineers are engaged in managing the activities of their fellow engineers; some reach executive levels of management where they supervise and coordinate the activities of scientists, engineers, technicians, craftsmen, and other non-technical employees in large corporations.

Research and Development

In the field of civil engineering, research and development activities are carried out to a great extent by university professors and

engineers employed in research institutes. At the same time, a significant amount of civil engineering research is carried out in laboratories and research organizations of federal and state governments. Federal and state governments support more than 50 percent of all the civil engineering research activities carried out in the United States today. It is likely that this government support will increase because of increasing governmental emphasis on research related to pollution control, improved transportation systems, and urban management activities.

In most research and development organizations, a specific problem or need is identified and then a team of engineers and scientists is established to find a solution to the problem. In most cases, the team will include scientists who are knowledgeable in basic principles and experienced in carrying out laboratory experimentation. The engineering members of these teams are more likely to be involved in the application of the scientists' findings in a practical way to the solution of the problem at hand. Research engineers must perform a coordinating function between the work of the basic scientists on the research team and the engineering designers or the consumers who have identified the particular problem under investigation or who have requested a particular project. The individual abilities and attributes necessary for successful work in research and development include high intellectual capabilities and a well-developed imagination. Basic research team members must have infinite patience and great self-confidence in order to continue their investigations, even if many of their efforts prove unsuccessful. It is necessary for research and development team members to be open to new ideas. They must be able to work well with others, sometimes in situations where everyone on the research and development team feels a great sense of frustration with their continued failure to find a solution to the problem at hand. Engineers working in research and development also must possess some other special qualifications. They must be adept at making accurate observations from experimental data and interpreting those data to draw the correct conclusions. After coming to a definite conclusion about a particular problem and developing a solution to that problem, the engineers must be able to convince the other members of the research and

development team, and more importantly, the other members of the affiliated professional organization of the quality and correctness of their solution. Research and development engineers must be able to present their ideas convincingly to their immediate supervisors and to top-level management. However, they must be willing to change their conclusions if evidence is presented to show that solutions are unsatisfactory in terms of cost or convenience to the user or client. After research and development engineers have determined a workable solution to a given research problem, they ordinarily turn their ideas and conclusions over to another team of engineers which applies the results of research efforts to the solution of specific problems. These planners and designers must take the basic concept of the system or solution developed by the research and development team and turn that idea into a set of definite plans and schedules for the construction and operation of a particular facility.

Planning and Design

One of the most important functions of civil engineers in planning and design is gathering basic data on the specific location at which a facility is to be constructed and on the specific needs and services at that specific location. In other words, in taking the results of research and development work and applying those results in actual practice, civil engineers must suit the results of the research and development work to actual conditions. In order to do this, they must obtain comprehensive data on the site conditions. They must test the soils and rocks at the project site; develop topographic and geologic maps; test environmental conditions in the area (air and water quality and water supply); and determine the technical characteristics of the man-made facilities in the immediate area of the proposed project. The investigation of man-made facilities may consist of determining the location, depth, and character of foundations of an existing building which cannot be disturbed by the construction of a new, adjacent structure. On the other hand, investigation of man-made facilities may consist of accurately locating all of the important structures in a particular area so that the route for a rapid transit system may be selected in the most efficient way. Obtaining

basic data necessary for the planning process may consist of determining the number and characteristics of the population in the area to be served by a particular project and of predicting the changes in number and character of the population in that area in years to come. After obtaining basic data of this sort, civil engineers utilize these data in developing both long-range and short-term plans to meet the needs of the community.

In preparing a design, civil engineers must take abstract concepts and transform them into a set of plans, drawings and accompanying specifications which can be utilized by contractors and builders to transform concepts and ideas into a physical reality in concrete, timber, steel, and other materials. Design is the function which is intermediate between research and development and actual construction. Specialists in other branches of engineering, such as mechanical and chemical engineering, often are engaged in formulating designs to be used in manufacturing processes. In contrast, the civil engineer almost always is engaged in developing a design for construction purposes. In formulating a design, engineers seek to make the best fit between the basic concept of a bridge, a structure, or a tunnel and the conditions existing at the site of the proposed facility. They select materials and construction methods with consideration for accomplishing the purposes of the basic design, but also with the knowledge of the availability and costs of materials at the site of the proposed facility. They must select materials for construction and specify methods of construction with an appreciation for the limitations of the labor force available in a particular location. For example, civil engineers engaged in designing a bridge to be built in a remote jungle location must recognize that both prefabricated materials and highly skilled laborers must be transported to the site of the proposed bridge. If it is possible to utilize locally available materials and unskilled labor in the construction of parts of the bridge, it may be possible to save considerable sums of money. In this case, the most sophisticated design for the bridge may not be the best design with respect to the overall cost of the structure. In the example of the construction of a bridge in a remote jungle location, the research work of materials scientists in developing high-strength steel alloys may be of little value if designers discover that transpor-

ting such materials to the remote location would be more expensive than using greater amounts of locally available materials. Additionally, designers must be capable of preparing plans and specifications which are easily understood by the individuals who are charged with construction. They must develop specifications which are clear and cannot be misunderstood by the laborers on the project site. Civil engineering designers must always be conscious that the lives and fortunes of many persons will rest upon the adequacy of their designs and upon the clarity and quality of the specifications they write.

Civil engineers obviously must be creative in order to develop new designs to suit particular conditions at specific locations. Additionally, they must be able to imagine structures and situations which do not yet exist. These situations will not exist until they have formulated appropriate designs and the structures have been built according to those designs. Designers must be able to express themselves clearly and accurately in both drawings and written instructions for the construction work. They must be able to choose between alternative methods of accomplishing the same purpose on the basis of engineering feasibility, cost, and environmental effects. In almost all cases, civil engineers will be called upon to act as part of design groups. The days of the single designer for a major structure have long since passed. Designers must be capable of working well with the other members of the design team; with the members of the research and development group to whom they turn for new ideas; and with the members of the field construction group responsible for putting their designs into practice.

Construction Supervision

Civil engineers who are primarily interested in supervising construction activities in the field must be capable of taking plans and specifications from design engineers and transforming them into a reality of steel, concrete, and other materials. This may be a difficult task since the plans for major structures often consist of hundreds of pages of drawings, varying from simple overall sketches of a proposed facility to complex diagrams of structural details. They may include hundreds of pages of written specifications describing

the methods to be used in accomplishing the proposed construction activities. Most civil engineers engaged in such activities are involved in the construction of bridges, highways, structures, and water and wastewater treatment-transport systems. In working on these projects, civil engineers will be called upon not only to supervise actual field construction activities but also to estimate project costs.

As mentioned earlier, engineers are responsible for accomplishing particular tasks with a minimum expenditure of money, materials, and labor. This is especially pertinent to the work of construction engineers, who must formulate a mental picture of the construction job from start to finish and schedule the arrival of materials, the use of equipment, and the employment of large numbers of specialist laborers. In general, construction engineers attempt to select the method of construction which will be most economical. They must minimize the cost of construction activities, but before they can do this, they must be able to make preliminary estimates of those costs in order to identify excessive expenditures. Engineers working for owners or developers of proposed facilities must be able to utilize construction estimates to evaluate bids of contractors wishing to do the work. Conversely, engineers working for bidding contractors must have the ability to make accurate cost estimates for the preparation of bid prices on proposed facilities. The preparation of bid prices is an important task of construction engineers. If their estimates are too low and contracts are awarded on the basis of their low bids, the contractors for whom they work may suffer financial loss when construction costs exceed their estimates. Likewise, if a construction engineer makes too high an estimate, the contractor might not be awarded the contract. Obviously, construction engineers working for contractors must develop a fine sense of balance in assessing costs and in judging the possible problems which may arise on a particular construction job.

If a contract is awarded to a particular contractor and work begins on the proposed project, the construction engineer will be charged with supervising the actual field work. This work will begin the actual layout of the project on the site by an engineering survey party. The survey party will place stakes and markers to show the

construction crew how to remove soil and rock to establish the proper elevations for the proposed structure. The surveyors will also place stakes and markers to show the locations for proposed facilities. After the surveying crew has established the proper grades and locations, the construction engineer must supervise the building of access roads to the project site. At this stage in the construction activity, structures may be built to house the labor force and to shelter the equipment and supplies to be used on the project. The construction engineer will be responsible for the arrangement and building of such structures. The construction engineer must be in constant communication with the design engineer so that, if the conditions on the job site encountered during construction appear to be different than they were assumed to be before construction began, the construction engineer can so inform the designer and the designer can modify his plans and specifications to meet the changed conditions. This close communication between field construction engineers and office designers is extremely important. Of course, one of the prime responsibilities of the construction engineer is the supervision and management of the labor force at the construction site. A civil engineer who wishes to be successful as a construction supervisor must be capable of maintaining good relations with the individual workers on the job site and with the group of workers as a whole. They must be constantly aware of the workers' needs and must be conscious of their safety at all times. Obviously, the construction engineer's work is extremely important to the successful implementation of the designer's plans and specifications.

Engineering Sales

Some individuals obtain their basic education in the field of civil engineering and then elect to represent various manufacturers in the sale of equipment and materials utilized in construction activities. To be successful, the sales engineer, must possess a fundamental education in engineering. It is no longer possible to sell materials and equipment to architects, engineers, and owners of complex and expensive facilities by means of a smooth line of sales talk and a collection of old jokes. The successful construction equipment and

materials salesperson should possess a background in engineering, preferably, in civil engineering.

The sales engineer must become intimately familiar with the machinery, products, or materials, which are manufactured by his employer. He must be capable of operating or utilizing his company products in an expert fashion and must be able to introduce new ideas to customers which display the advantages of his company's products. He also must be very skillful in understanding customers' needs and in understanding their complaints about furnished materials and machinery. He should be capable of returning from a trip to customers' offices and describing to his employer's design engineers the needs and desires of those customers, and of identifying for the designers the major problems in the field use of his employer's products. Also, he must be aware of competitors' developments in machinery and materials. Most graduates from civil engineering curricula pursue careers as engineers rather than in sales, but the importance of a background in civil engineering to a person selling construction equipment or materials cannot be overemphasized.

Management

It is difficult to precisely define management in terms of an engineering career, because almost all engineers are engaged in some form of management in some way. In other words, engineers will be charged with supervising their fellow engineers in a design office or on a research team, or they may be responsible for managing a construction project in the field, even though they may not consider themselves to be a part of the "management" effort. Management generally is characterized by decision-making. The basic duty of the manager is to choose between alternative ways to employ people, equipment, and materials in order to accomplish a particular task. From this viewpoint, any type of supervisory or decision-making activity on the part of engineers could be considered to constitute management. However, when most engineers talk about "management," they mean the activities of an executive who is responsible for making decisions which affect large groups of people, or which influence the spending of large sums of money. Many engineers

function as managers when they are active as project engineers, chief engineers, branch or district engineers in agencies, and at other levels of management characterized by supervising small numbers of their fellow workers. Many of these individuals only consider themselves "managers" when they are forced to abandon their own engineering and technical work and devote almost all of their time to making major decisions concerning the allocation of labor and materials in accomplishing overall project objectives.

Since managers are considered to be those who make important decisions concerning the employment of large numbers of people or the expenditure of large sums of money, it is obvious that management is very important and exacting activity. Why would engineers be attracted to management roles? One of the most obvious reasons is that, in general, managers and executives are richly rewarded in terms of salary and other benefits. Typically, the chief executive of a corporation will be rewarded with a salary three to four times as high as the highest paid engineer employed by that corporation. Many times the upper-level managers in corporations or in companies may be rewarded with a share in the profits or with part ownership of the company or corporation. The financial returns for management activities generally are higher than those associated with engineering activities. Other attractions to management careers include the opportunity to make important decisions. Many individuals seek challenge in life and feel rewarded when they are given the opportunity to make decisions affecting large numbers of persons or large sums of money. It has been stated in many articles and books that the most obvious attractions to management careers are the power associated with management positions and the individual status that a person achieves with such power. However, it is an over-simplification to say that most engineers who enter management do so simply to achieve status. It is much more meaningful to observe that most managers are motivated by the challenge of making important decisions. In making these decisions, managers must call upon their technical background and also on their ability to utilize fellow workers to their greatest potential. They must be creative and imaginative in developing new solutions to old problems. In all of these activities, managers who possess a certain type

of personality will feel a great sense of achievement and accomplishment. On the other hand, certain individuals will find careers in management totally unattractive because of some of the disadvantages inherent in management activities. One of the most serious disadvantages of a management career is the high level of emotional stress under which most executives continually work. The emotional stress may arise from the necessity to make important decisions or it may be created by the need for a manager to hold his own emotions in check in order to maintain pleasant working relationships with his colleagues and subordinates. Engineers entering management careers will usually feel the necessity to conform to the opinions and practices of managers at higher levels within their organizations. That is, young managers will be forced to suppress some of their own individuality in seeking to conform to a company or corporate image. This feeling of the need to conform to a corporate image may even extend to the way the young manager dresses and entertains. Some individuals cannot accept these restraints on their individual freedoms, or they cannot accept the effects of such constraints on their home life. Some find the "office politics" that are associated with management activities unacceptable and for this reason decline opportunities and offers to enter management careers. In some cases, engineers decline to enter management careers because of their fears that their own standards of personal morality may conflict with the policies of the company or corporation in which they are employed.

Before a person embarks on a career in management, it would be wise for that individual to consider some of the demands made on managers. The successful manager must be capable of handling personnel, both technical and non-technical. The manager must desire to be in a decision-making position and must feel comfortable in control of the destinies of his fellow workers and of customers or clients affected by his activities. In general, the successful manager must show a willingness to place the interests of the company or corporation ahead of his own interests. He must be willing to spend long hours in working toward his goal and must be motivated by a strong desire for personal status. Since his rise to top level management may not be rapid, he must be capable of enduring numerous disappointments and he must be optimistic about his chances to

eventually succeed. Obviously, if he is to succeed, he must be able to persevere in accomplishing a given task and he must be capable of exercising good judgment in making basic decisions. Additionally, he must be able to convey to his fellow workers and his fellow managers his ideas on management, his decisions and choices between alternatives, and the degree to which his decisions may be better than the decisions made by others. If an individual examines all of these demands associated with a management career, and if he also is interested in the field of civil engineering, he will find that an education in civil engineering will serve as an excellent foundation for an initial career in the technical field of civil engineering followed by a subsequent career in management.

Consulting Engineering

At this point, it is pertinent to mention the opportunities for civil engineers to be self-employed as consultants. Consulting engineering is a field of specialization which includes all of the functional specialities mentioned in the paragraphs above. Basically, a civil engineer who wishes to be a consultant must be a registered professional engineer in the state in which he or she establishes his or her own office and then offer services to any clients who wish to employ him or her. Most civil engineers pursue consulting activities of a general nature. Their day-to-day activities may include the gathering of basic data such as the conduct of a land survey, the measurement of traffic at a particular location, or the determination of the flow in a particular waterway. In addition to these activities in gathering basic data necessary for design activities, consulting civil engineers very commonly are called upon to develop plans and designs on the basis of the data they have gathered, or which has been gathered by other engineers. The civil consulting engineer may be engaged in any one of the particular technical specializations which were mentioned in the first part of this chapter. Many civil consulting engineers are engaged in surveying activities; in structural planning and design; in design of transportation systems; in geotechnical engineering; in environmental engineering; in urban planning; and in public works consulting capacities. In public works consulting, generally the civil

engineer makes his considerable experience and educational attainments available in the form of direct advice to municipal officials and public works engineers in answer to their questions concerning the best possible solutions to particular problems associated with an urban community. Consulting engineers in other areas of technical specialization at times may be engaged in research and development activities; in gathering basic data for planning purposes; in formulating designs for specific projects; in representing an owner or a client as a supervisor on a particular project; or in exercising a management role in coordinating the activities of a number of other engineers. Obviously, if a consultant is successful and wishes to expand his activities he may employ other engineers who then assume portions of his work load. With continued success, the consulting engineer must assume the role of a manager in supervising the work of his associates. If his consulting firm grows to the point where it has large financial resources and employs considerable numbers of personnel, the consulting engineer may find himself functioning primarily as an executive, with little time devoted to actual engineering work of his own.

The vast spectrum of activities which are available to a person considering a career in civil engineering should be obvious from the descriptions contained in the preceding paragraphs. In pursuing a career in any one of these technical specializations, at any one of the levels of functional specialization described above, the civil engineer can look forward to adequate compensation in the form of a high salary, excellent fringe benefits, and relatively stable employment conditions. Salaries and conditions of employment are described in the next chapter.

CHAPTER 4

JOB DUTIES, SALARIES, WORKING CONDITIONS

In the preceding chapters, the many branches of civil engineering were described. Examples and detailed descriptions were given of the various types of educational programs available to a prospective engineer to prepare him for entry into the profession. However, it may not be entirely clear at this point just what type of work an engineer will perform in the areas of specialization described. Therefore, to clarify these points, a short description of possible job duties in a few of these areas of Civil Engineering is given below. This description of job duties will indicate the nature of work which probably would be required of a Civil Engineer entering each area of practice.

Past experience has indicated that, for a recent graduate, finding the right type of work, work that is both a challenge and that offers opportunity for advancement, is more important than getting a high starting salary. It has been observed that salary almost never appears at the top of the list when engineers are asked to indicate those items that are important in the ideal job. Instead, it modestly shows up in third or fourth place. The most desirable job characteristics are: 1) opportunity for advancement; 2) creative, challenging work; 3) good salary; 4) recognition of achievement; and 5) the chance to keep up with new developments.

Some persons have interpreted this ranking to mean that engineers have little interest in money. However, it is more likely that most engineers simply have not experienced the need to worry about salaries because they have been pretty much in a "seller's market" since 1950.

SPECIFIC JOB DUTIES

In the field of civil engineering, as stated in Chapter 3, the types of job duties available to a person working as a professional are quite varied, because of the many areas of specialization in civil engineering. In addition to the various areas in which the practitioner may work, as in any profession, there are levels of experience which to some degree determine the responsibilities that will be assigned to a particular person. The young engineer usually will start at a level with moderate responsibility, and, as he gains experience, will be assigned more important decisions to make.

At the lower levels of engineering responsibility, for example, the engineer may be assigned the duties of a surveyor in the precise layout of facilities. He may be engaged in the development of plans and designs for the construction of major engineering works. The structural designer ordinarily is concerned with the most economical use of materials to produce the desired functional structures.

The structural engineer must determine the loads to which the structure will be exposed (wind, snow, stoned materials, etc.). Then, from his knowledge of loads and materials, he must calculate the forces imposed and select the most efficient combination of materials and structural elements to carry the loading.

In the water resources area, the engineer will be required to study the demand by the community for water supplies and sewerage facilities. He will then be required to design water treatment facilities as well as a distribution and collection system that will assure water and a safe and healthful disposal of wastewaters.

It will be necessary for the civil engineer to closely study population trends and suburban developments in his role as a partner in the urban planning team or the municipal engineering group; it will be necessary for him to plan and provide all of the required public services, in advance of the time when people move into the newer areas of the community. The public works engineer also must anticipate and be responsive to the social needs of the community.

A new but major area of responsibility for the civil engineer today is his relationship to the environment. He will be responsible for the engineering works associated with the control of water, air, and land

pollution. He will be called upon to prepare or contribute to environmental impact statements which are developed to determine the environmental effects of engineering works.

The highway engineer daily plans, designs, constructs, and maintains many miles and literally billions of dollars worth of highways in the United States. This field is a major area of civil engineering employment today, and will remain so for decades to come.

In summary, the available variety of job duties is so wide that there is little likelihood today that any civil engineering graduate will not find several jobs that will match his desires, education training and experience.

TYPICAL ASSIGNMENTS FOR BEGINNING CIVIL ENGINEERS

Since the beginning civil engineer has only a limited amount of professional experience, the responsibility that he can be given on his first few assignments is somewhat limited. However, most employers will attempt to develop the young engineer professionally as rapidly as possible, since he becomes more valuable to any employer when he can accept the responsibility for major engineering decisions based upon his professional experience.

The beginning engineer will usually, of necessity, start his career in a position in which the decisions to be made require academic rather than professional experience. Positions such as instrument man or chief of a surveying party; field inspector (materials testing) on a construction site; cost estimator or one of the other positions associated with small or medium construction contracts; are typical of usual first assignments. If the new engineer accepts a position with a consulting firm or a government agency he is likely to find himself working closely with, and under the supervision of, a more experienced engineer on the design of a bridge, building, highway or even a water supply or pollution control facility.

An engineer accepting his first position with a city or county government will find himself dealing almost at once with the public, in handling engineering aspects in zoning cases, improvements to

city streets and buildings or other engineering aspects of running a city today. He may be assigned the task of being the agency's liaison between the contractor, who holds a contract for perform an engineering task for the city, and the elected officials who are charged with the responsibility of providing the public with a required service. He may be assigned to meet with neighborhood groups to explain the agency's position with respect to some decision on an engineering improvement or project.

Frequently, the beginning engineer will be assigned the task of gathering and assembling the engineering data needed to allow the more experienced professional to make a major technical decision or complete a design. All of these beginning assignments will assist the young engineer to gain the experience necessary to mature professionally.

RESPONSIBILITIES FOR EXPERIENCED PROFESSIONALS

With professional experience added responsibilities will come to the professional, and, of course, he will receive added compensation and recognition within the firm. Perhaps one of the most complete and detailed statements of this progression of responsibility, with experience, is the classification of professional grades published by the American Society of Civil Engineers, for purposes of establishing membership grades and determining recommended levels of compensation. Exerpts from the ASCE grade description as given below, if carefully studied, will show the close correlation between professional attainment, experience, and maturity.

The following descriptions of job responsibilities have been condensed for inclusion in this text. The complete descriptions (and full document) are available from The American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017.

For the professional civil engineer, the ability and willingness to accept increasing amounts of responsibility and decision making is of paramount importance. Since the civil engineer is constantly dealing with the health and safety of the general public, incompetence

Engineer Grade	Typical Duties and Responsibilities	Typical Position Titles
I/II	Using prescribed methods, performs specific and limited portions of a broader assignment of an experience engineer. Applies standard practices and techniques in specific situations, adjusts, and correlates data.	Junior Engineer, Associate, Detail Engineer, Engineer-in-Training, Ass't. Research Engineer Construction Inspector
III	Performs work which involves types of plans, investigations, surveys, structures, or equipment with relatively few complex features for which there are precedents. Assignments usually include activities of limited scope requiring knowledge of principles and techniques commonly employed in the specific narrow area of assignments.	Engineer or Assistant Engineer, Project, Plant, Office, Design, Process, Research, Inspector, Engineering Instructor
IV	Plans, schedules, conducts, or coordinates detailed phases of the engineering work in a part of a major project or in a total project of moderate scope. Performs work which involves conventional engineering practice but may include a variety of complex features such as conflicting design requirements, unsuitability of conventional materials, and difficult coordination requirements. Work requires a broad knowledge of precedents in the speciality area and a good knowledge of principles and practices of related specialties.	Engineer or Assistant Engineer, Resident, Project Plant, Office, Design, Process, Research, Chief Inspector, Assistant Professor

Engineer Grade	Typical Duties and Responsibilities	Typical Position Titles
V	One or more of the following: (1) In a supervisory capacity, plans, develops, coordinates, and directs a large and important engineering project or a number of small projects with many complex features. (2) As individual researcher or worker, carries out complex or novel assignments requiring the development of new or improved techniques and procedures. (3) As staff specialist, develops and evaluates plans and criteria for a variety of projects and activities to be carried out by others. Assesses the feasibility and soundness of proposed engineering evaluation tests, products or equipment when necessary data are insufficient or confirmation by testing is advisable.	Senior or Principal Engineer, Resident, Project, Office, Design, Process, Research, Ass't, Division Engineer, Associate Professor, Project Leader
VI	One or more of the following: (1) In a supervisory capacity (a) plans, develops, coordinates, and directs a number of large and important projects or a project of major scope and importance, or (b) is responsible for the entire engineering program of an organization when the program is of limited complexity and scope. The extent of his responsibilities generally require a few (3 to 5) subordinate supervisors or team leaders with at least one in a position comparable to level V. (2) As individual researcher or worker conceives, plans, and conducts research in problem	Senior or Principal Engineer, Division or District Engineer, Production Engineer, Assistant Division, District or Chief Engineer, Consultant, Professor, City or County Engineer

Engineer Grade	Typical Duties and Responsibilities	Typical Position Titles
	areas of considerable scope and complexity. At this level, the individual researcher generally will have contributed inventions, new designs, or techniques which are of material significance in the solution of important problems. (3) As a staff specialist for the organization (division or company) in the application of advanced theories, concepts, principles, and processes for an assigned area of responsibility.	
VII	One or both of the following: (1) in a supervisory capacity is responsible for (a) an important segment of the engineering program of a organization with extensive and diversified engineering requirements, or (b) the entire engineering program of an organization when it is more limited in scope. The overall engineering program contains critical problems the solution of which requires major technological advances and opens the way for extensive related development. The extent of his responsibilities generally requires several subordinate organizational segments or teams. (2) As individual researcher and consultant is a recognized leader and authority in his organization in a broad area of specialization or in a narrow but intensely specialized field. Selects research problems to further the organization's	Principal Engineer, Division or District Engineer, Department Manager, Director or Assistant Director of Research, Consultant, Professor, Distinguished Professor or Department Head, Assistant Chief or Chief Engineer, City or County Engineer

Engineer Grade	Typical Duties and Responsibilities	Typical Position Titles
	objectives is consulted extensively by associates and others with a high degree of reliance placed on his interpretations and advice.	
VIII	One or both of the following: (1) In a supervisory capacity is responsible for (a) an important segment of a very extensive and diversified highly engineering program, or (b) the entire engineering program when the program is of moderate scope. The programs are of such complexity that they are of critical importance to overall objectives, include problems of extraordinary difficulty that often have resisted solution and consist of several segments requiring subordinate supervisors. Is responsible for deciding the kind and extent of engineering and related programs needed for objectives of the organization, for choosing the scientific approaches, for planning and organizing facilities and programs, and for interpreting results: (2) As individual researcher and consultant, formulates and guides the attack on problems of exceptional difficulty and marked importance to the organization or industry.	Chief Engineer, Bureau Engineer, Director of Research, Department Head or Dean, County Engineer, City Engineer, Director of Public Works, Senior Fellow, Senior Staff, Senior Advisor, Senior Consultant, Engineering Manager
IX	No responsibilities detailed.	Director of Engineering, General Manager, Vice President, Partner, Dean, Director of Public Works

in a position of responsibility cannot be tolerated. As in any profession, advancement will be closely related to the individual's performance of job duties and fulfillment of responsibilities.

Wages and Salaries

As a professional person, the young engineering graduate will receive a salary consistent with the education required to obtain a degree and also proportional to the importance of the work that he will be assigned. The rate at which an engineer just out of college advances in salary for the first several years is almost independent of his performance, unless that performance is unacceptable and he is released. If he is judged sufficiently valuable to continue on the payroll, his salary increases in the first year or two will practically be automatic. After this probationary or training period, the quality of his individual performance will begin to show its influence, with the truly outstanding person moving ahead very rapidly. A competent engineer can expect more or less steady salary growth for at least as long as five to ten years.

In addition to the steady salary growth in engineering, the civil engineer, along with all engineering graduates, can expect receive a higher starting salary than most other professionals.

The starting salaries of graduate engineers, compared with those of four-year college graduates in other fields, have consistently been better. Based on Dr. F. S. Endicott's annual reports from 1956 to 1974,¹ starting salaries for engineers have regularly exceeded those of other four-year graduates. Engineers' starting salaries are the highest, followed in order by accounting, chemistry, sales, economics, business and liberal arts (Table 1).

Figure 1, below, shows the average monthly starting salaries for all new engineering and technology graduates for the years 1961 through 1975. This figure clearly shows the increasing trend in all starting salaries as well as the increment in the starting salary for those graduates holding advanced degrees. Figure 2 shows compar-

¹Frank S. Endicott, *Trends in Employment of College and University Graduates in Business and Industry*, for year shown. Frank S. Endicott, director of placement, Northwestern University.

Table I. Starting salaries (monthly rates)⁽¹⁾

	Engi- neering	Sales	Account- ing	Lib. Arts	Chem- istry	Eco- nomics	Busi- ness
1956	\$415	\$370	\$372				\$363
1957	454	398	402				393
1958	472	412	417				407
1959	489	422	433				411
1960	510	440	446	N/A	N/A	N/A	427
1961	529	453	462				435
1962	554	468	488				466
1963	580	488	508				482
1964	613	508	537				490
1965	632	521	561				520
1966	676	562	594				548
1967	712	583	612				572
1968	764	626	681				622
1969	818	669	737				668
1970	872	715	840	\$682	\$809	\$740	677
1971	885	742	845	690	826	768	695
1972	884	784	873	702	831	777	704
1973	905	804	902	724	843	790	722
1974	995	840	956	745	930	842	777
1975	1062	862	990	776	992	851	812

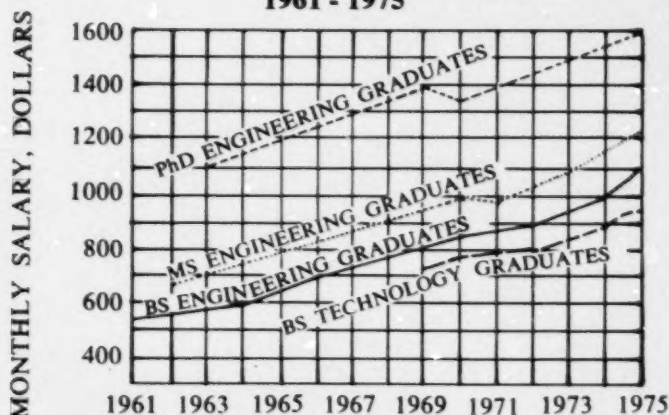
¹Frank S. Endicott, *Trends in Employment of College and University Graduates in Business and Industry*, for year shown. Frank S. Endicott, director of placement, Northwestern University.

able data for civil engineering graduates only.

As an indication of the salary increases accompanying professional experience and added responsibilities, Table 2 is presented on the next page. This figure was taken from the same 1975 ASCE salary survey as was Figure 2. This figure shows the median salaries and range of the middle 50%, for a sampling of civil engineers employed by consulting engineering firms, with experience placing them in the various ASCE grades I through IX, as explained in the previous article.

As noted previously, the professional's salary, both median and maximum, advances regularly with increasing experience and decision-making capability.

AVERAGE MONTHLY STARTING SALARIES OF NEW ENGINEERING AND TECHNOLOGY GRADUATES 1961 - 1975



Source: Engineering salaries adapted from annual surveys by The College Placement Council, Inc. Technology salaries from annual surveys by the Engineering Manpower Commission.

FIGURE 1

Fringe Benefits

While the direct salary associated with a civil engineering position is probably one of the most important factors to be considered in evaluation of an employment offer, the total compensation, which includes the direct salary plus any fringe benefits offered, often is even more important. Every position, without exception, offers some type of fringe benefit package; some are quite large while others are modest, but all are important to the prospective professional employee. Among the more common benefits to be expected in practically all civil engineering positions are paid vacations, holidays, sick leave, retirement pay and workman's compensation. Many firms and

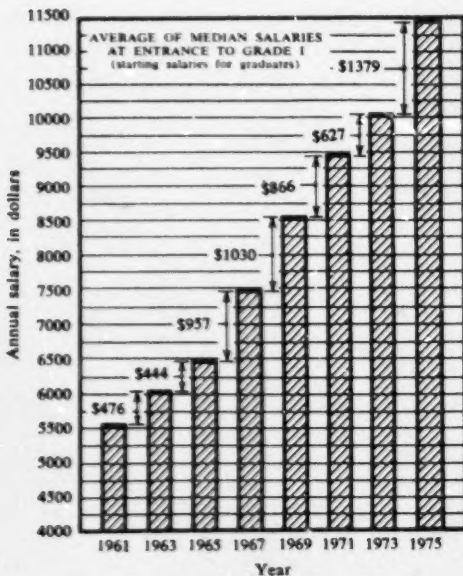


FIG. 2. CIVIL ENGINEERING GRADUATES ONLY*

From 1975 Salary Survey - Committee on Employment Conditions of The Department of Professional Activities - American Society of Civil Engineers.

agencies will have, in addition to the above benefits, one or more of the following: military leave or jury duty pay; incentive compensation; payment of professional society dues, licenses and meeting expenses; paid insurance (both life and medical); payments for educational expenses; profit sharing; and, occasionally, the free use of company-owned recreational facilities. Depending upon the particular package of fringe benefits offered, the total compensation may vary from as low as 150 percent to over 200 percent of the total direct salary offered. The prospective employee must therefore give

1975 SALARY SURVEY
TABLE 2.—Consulting Firms

ANNUAL SALARIES, in \$				
ASCE grade (1)	Entrance Rates		Maximum Rates	
	Median (2)	Middle 50% (3)	Median (4)	Middle 50% (5)
I/II	10,800	9,600 12,000	13,200	12,000 15,000
III	12,600	11,900 14,000	15,500	14,000 17,400
IV	14,650	13,500 16,000	18,000	16,000 20,000
V	16,800	15,000 18,000	20,500	18,000 23,400
VI	19,219	17,400 22,000	24,000	20,500 27,000
VII	22,000	19,500 25,000	27,000	24,000 30,600
VIII	25,000	22,000 30,000	32,000	27,800 38,000
IX	30,000	25,000 37,000	42,000	32,500 54,000
Av.	18,884		24,025	

Notes: (1) Average of median entrance rates, all grades, in 1973 was \$16,067; Percent change 1973-1975 is + 17.5%

Source: same as Fig. 2

careful consideration to the fringe benefits offered by a firm or agency. In general, it can be stated that the higher the percentage of fringe benefits offered, the lower will be the direct salary that can be expected in a particular position.

GENERAL EMPLOYMENT CONDITIONS

Since the civil engineer is a professional person, he or she will find that his general employment conditions will be quite different from

those of the tradesman, the vocational worker and other non-professional employees. It is considered inappropriate for a professional employee to use a time clock to record his arrival and departure, particularly since situations will arise which may require unusual effort and late hours. In general, unless this overtime occurs on a regular basis, the civil engineer will not be compensated directly for this extra work. The professional employee will usually be continually informed of the firm's objectives, policies and goals, since in many cases he will be considered a part of the firm's management. He will usually be provided with a well-appointed office, adequate support staff and physical facilities which will promote his maximum personal efficiency. His duties and levels of responsibility will be clearly defined by the firm or agency management and will be reflected in his position and title. Of course, because of this professional position in the firm or agency, the civil engineer has obligations to the employer over and above those of the non-professional. He must be loyal to his employer; he must accept only assignments for which he is qualified; he must be diligent, competent, and honest in completing his assigned duties; he should contribute creative, resourceful ideas to his employer; and finally, he must have due regard for safety, life, and health of the public and his fellow employees.

The professional employee must be careful to avoid any conflict of interest or the disclosure of any technical proprietary information that would have any adverse effects on his employer or firm. In summary, he should expect not only to be treated as a professional but also to accord professional treatment and consideration to his employer and fellow employees.

OVERALL DEMAND FOR CIVIL ENGINEERS: PAST, PRESENT, AND FUTURE

Since the beginning of World War II in 1939, technological change in the United States has taken place at an unprecedented and ever-increasing rate. This change has been reflected in the style and standard of living throughout the United States and Western Europe. As a result, requirements for engineering knowledge and

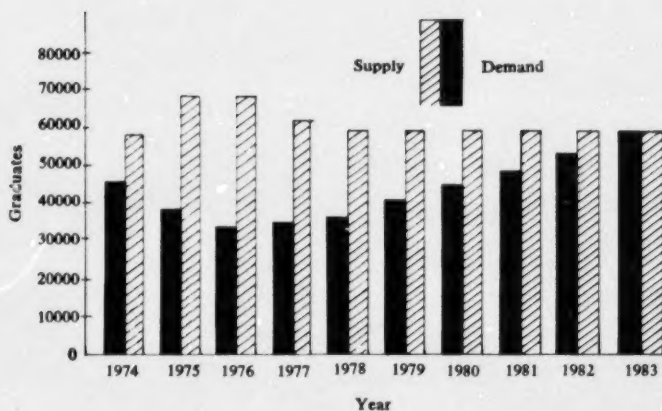
skills have increased rapidly since the early 1940s. This has led to a corresponding increase in the demand by industry and government for all types of engineers, including civil engineers, since that time. In 1930, there were 4.6 engineers per 1,000 persons gainfully employed in the United States. By 1940, this figure had risen to 5.2; by 1960 it had moved up to 12.2; and, in 1970, it had reached a ratio of 15.4. During this period the number of engineers employed in the United States increased from less than 230,000 to over 1,200,000, an increase of over 400 percent.

This trend of increasing ratios of engineers to other employees, shows no signs of abating. It is currently estimated, by the U. S. Department of Labor, that, by 1980, the required engineering labor force will reach 1,500,000. This has led many in the profession to conclude that the supply of new engineering graduates cannot catch up with the expected demand before the mid 1980s at the earliest. There are clear signs that industry cannot now hire as many new engineers as it would like. These circumstances are not likely to change in the immediate future. The College Placement Council reported in its 1975 mid-winter survey that 59 percent of all job offers being made to June 1974 graduating classes were going to engineers. The next most numerous species were accountants with 18 percent, and only 5 percent of offers were being made to humanities and social science majors.

The consequences of too few engineers graduating to satisfy industry's needs can be readily predicted. Industry will be forced to make do with what it can get. Recruiting will become a much more competitive business, and raiding more aggressive. Salaries and benefits will be forced upward at an accelerated pace. All of this points to an exciting time for the civil engineering graduate of the 1980s.

The figure shown on the next page reflects the predicted supply and demand for engineering graduates through the year 1982. Only in the early 1980s will the supply approach the demand, under present projections.

The demand for Civil Engineering graduates has been steadily climbing for the past 10 years. With increasing concern for the environment and demand for public works and social programs, the demand for Civil Engineers over the next decade should outstrip even the greatest demand for other types of engineering graduates.



CHAPTER 5

EMPLOYMENT AND ADVANCEMENT

The general working conditions, salaries, and benefits for civil engineers were described in the last chapter. In this chapter, the stability of employment in the field of civil engineering will be described. Also, the steps to be taken by the recent civil engineering graduate, or the civil engineer desiring to change positions, in finding employment will be described. In general, the unemployment rate for civil engineers is extremely low and the new graduate will find a steady demand for his services. It will be much more important for that graduate to choose the job most appropriate to his desires and capabilities rather than to worry about unemployment. After the young engineer has selected a job and has been employed for a time, there are various paths that he can follow to achieve professional advancement. Those paths to career advancement also will be described in this chapter.

JOBS?

In any discussion of employment and advancement in a given career field, one of the most important considerations is the stability of employment. In other words, is there likely to be a variable demand for individuals engaged in a particular type of activity so that periods of high salary and many job offers alternate with periods of unemployment? A great deal has been written and spoken in the past ten years on the stability of the job market in engineering and in civil engineering, in particular. There has been continuing controversy

over whether or not there will be enough engineers to meet projected demands. Because of the publicity which has been generated on this question, engineering enrollments have shown great fluctuations. Shortly after the Second World War, with the return of many servicemen to schools and colleges in the United States, engineering enrollments reached a peak, with more than 80,000 freshmen enrolling in engineering courses in 1946. In the five years from 1946 to 1951, however, freshmen enrollments dropped to approximately 35,000. What caused this rapid and serious decline in the number of freshmen college students choosing engineering as a career?

Shortly after World War II, the federal government released statistical analyses of the engineering profession, including predictions for jobs in the coming years. These predictions included a warning that, with the anticipated enrollments of more students in engineering courses (at the 80,000 per year level), a surplus of engineers soon would be created in the United States. This prediction was given great publicity in newspapers and magazines. As a result, many high school seniors decided to enter other careers and freshmen enrollments in engineering dropped severely. Then, in the early 1950s, with the advent of the Korean War and the increased need for engineers and technically trained specialists, freshmen enrollments in engineering increased. By 1956, freshmen enrollments in engineering had again reached the level of about 80,000, corresponding to the 1946 peak. During these years, continued emphasis was given to the need for scientists and engineers by the growing competition between the United States and the Soviet Union, particularly in aerospace activities. Again, however, the rapid increase in freshman enrollments led to predictions that the job market would be flooded with graduate engineers in the early 1960's. As a result of this wave of adverse publicity, a new drop in freshman enrollments occurred, to a level of about 65,000 in 1962 and 1963. Of course, these changes in the numbers of college freshmen enrolling in engineering courses were reflected in similar increases and decreases in the number of persons graduating from engineering curricula. For example, the peak enrollment of over 80,000 freshmen in engineering in 1946 yielded more than 50,000 engineering graduates in 1950. The rapid decrease in freshmen enrollments in engineering, with a low of about

35,000 in 1950, produced a corresponding decrease in the number of engineering degrees awarded four years latter, with a low point of approximately 25,000 bachelor's degrees in engineering in 1954 and 1955.

The middle 1960s saw a significant increase in the number of freshmen enrolling in engineering curricula, primarily as a result of the greatly expanded requirements for engineers in aerospace activities. The federal government has published statistics which showed that the demand for engineers and scientists in 1965 and 1966 was more than twice as great as the demand for engineers and scientists in 1960. The rise in enrollments was reflected in a steady increase in the number of engineering graduates from 1965 to 1970.

The economic recession and the decrease in demand for engineers in the late 1960s and early 1970s was again publicized widely. A large proportion of the engineers and scientists who were suddenly unemployed had been active in the aerospace and defense programs. Some of the most serious cutbacks in the aerospace and defense industries were experienced at the executive level of management and at the senior scientist/engineer level. As a result, many of the newly unemployed engineers were persons with years of experience and advanced degrees, particularly Ph.D.s. The situation of Ph.D. engineers with 15 years experience being suddenly out of work, or employed as janitors and taxi drivers, made excellent material for television news programs, newspaper, and magazine articles. As a result of this burst of negative publicity, freshmen enrollments in engineering correspondingly dropped to approximately 50,000 in 1973. As a result, the number of engineering graduates in the middle 1970s has steadily declined. However, at the present time, freshmen enrollments have begun to increase steadily again, and numbers of graduates in engineering should increase correspondingly in the next five to ten years.

Can a person make any sense out of these recurrent swings in demand and supply? It is possible to clear up a considerable amount of the confusion by focusing attention, not on the number of students in engineering courses and the number of graduates from engineering schools, but on the number of engineers who could not find suitable employment during these same times.

The United States Bureau of Labor Statistics compiles data on the unemployment rates for a variety of professions. The Bureau data on unemployment rates for engineers show that the maximum employment rate in the ten years from 1963 to 1973, for engineers, was slightly more than 3 percent in early 1971. This unemployment rate was approximately half the rate for all workers in the United States at that time. In contrast, the average unemployment rate for the six year span from 1963 to 1969 was approximately 1 percent with the highest rate being slightly more than 2 percent in early 1964 and the lowest unemployment rate being less than 0.5 percent in late 1966. Since the great decline in the demand for aerospace and defense engineers in the early 1970's, the unemployment rate for engineers has dropped from the all-time high of 3.2 percent in 1971 to a level of approximately 1 to 1½ percent in the mid-1970s. Thus, it appears that even when considerable nationwide publicity was given to the tremendous unemployment problems of engineers, the unemployment rate for professional engineers was less than half the unemployment rate for all workers in the United States.

What can be reported about the unemployment rate for civil engineers? In general, the unemployment rate, associated with fluctuations in supply and demand, varies much less from year to year for civil engineers than for engineers in other branches. There are several reasons for this relatively constant, low rate of unemployment for civil engineers. First, civil engineers are engaged in activities which for the most part are associated with the necessary day-to-day activities of today's society. The various engineering specializations which were described in Chapter 3 correspond to activities necessary for the health and welfare of the population. For example, it is hard to imagine that a civil engineer engaged in obtaining and distributing water supplies to a large American city suddenly would be unemployed as a result of a minor economic recession. Civil engineers engaged in other forms of public works activities such as solid waste management, wastewater treatment, traffic control, and other similar activities are hardly candidates for being among the unemployed even during periods of economic depression.

A second factor which helps to prevent any drastic fluctuations in the demand for civil engineers is the fact that in times of economic

depression, the federal government in the United States traditionally has attempted to revitalize the national economy by authorizing and financing vast public works activities. Of course, these activities must be planned, designed and supervised by civil engineers. As a consequence, civil engineers are in demand even when some of their professional colleagues in architecture or other branches of engineering may be unemployed.

A third factor tending to lead to a more constant demand for civil engineers, when compared to that for other types of engineers, is the fact that many civil engineers are employed by federal, state, and local governments, and are not subject to the hiring and firing policies of industrial corporations. In general, employment with governmental agencies is much steadier and more secure than employment with private corporations.

Finally, another factor in the relatively steady demand for civil engineers arises from the fact that civil engineers generally are able to find employment in all parts of the world. Civil engineers, in contrast to other types of engineers whose activities are directly related to industrial societies, may be employed in "developing" nations on public works projects designed to improve living conditions in those countries. In times when market fluctuations restrict industrial output, and possibly lead to unemployment of engineers associated with manufacturing and industrial production, civil engineers will find relatively steady employment since their activities are related to long-term goals of improving living conditions and developing water supply, power and transportation systems, and the structures and facilities related to such systems. In this connection, it is interesting to note that in the period of greatest fluctuation in the demand for engineers as a whole, in the late 1960s and early 1970s, freshmen enrollments in civil engineering have grown steadily and the number of graduates obtaining bachelor's degrees in civil engineering has increased approximately 50% in the same time period.

Since this brief analysis of the job market indicates that civil engineering graduates will find little difficulty in obtaining employment, it appears that it may be more important for a person considering a career in civil engineering to think about choosing the right job,

rather than being concerned with whether or not a job with be available.

CHOOSING A JOB

The prospective graduate of a civil engineering curriculum is likely to be confronted with a considerable list of job offers and opportunities in the weeks before graduation. Most of these job offers will appear to be worthwhile and relatively attractive. This is logical, since recruiters who visit college campuses attempt to present their companies and agencies in as favorable a light as possible. As a consequence, the new civil engineer may be faced with a serious problem in selecting that one job which will best suit his individual capabilities and desires.

In order to select that one "best" job, the prospective graduate, and even the experienced civil engineer seeking a new job, should evaluate several major factors concerning job offers. These factors include: personal preferences; the professional reputation of the prospective employer; the opportunities for career advancement, including continued education in the jobs offered; and the salary, fringe benefits, and job security conditions which accompany a particular job offer.

Personal Preferences

The most important factor for a job candidate in civil engineering to consider when he is evaluating an offer of employment is his personal reaction to the description of the work and duties to which he would be assigned. In other words, if he hopes to be successful in that job, it must have a personal appeal to him.

In all probability, the job offer will be in the field of civil engineering; however, occasionally employers will approach civil engineering graduates with offers for work in other fields of activity such as sales, or elementary levels of management. Some individuals may find such offers attractive and may be successful in applying their personal capabilities and their newly gained knowledge in such a field. However, such individuals constitute a small minority of the civil

engineering graduates produced each year in the United States. The new civil engineering graduate would be well-advised to select a job in the field of civil engineering as an initial phase in his career rather than be persuaded to enter another field on the basis of higher pay or similar inducements. After the new graduate has gained some experience in a particular job assignment, he will be better prepared to undertake work in other fields such as sales. If the new graduate chooses to enter a completely different field of endeavor such as sales or management, he stands a greater chance of being dissatisfied with his first work assignment than he would if he were to enter the technical fields of specialization in civil engineering, since most of his experiences in college have given him exposure to technical civil engineering work. If the graduate undertakes a job assignment in which he is unhappy, he is likely to be an unsuccessful worker, in whatever field he has chosen. Consequently, his chances for advancement in that field will be minimal.

The prospective graduate from a civil engineering curriculum also should evaluate the conditions of work associated with any particular job offer. If an individual is fond of working and living in the outdoors, he might be quite well pleased with the work of a construction engineer. However, if he prefers to work in an office or in a research establishment, construction supervision at a remote location in all sorts of weather would be quite unattractive to him. The geographical location of the job assignment, whether it is in a large metropolitan area or in a smaller community, can be an asset or a liability to a particular job, depending upon the desires of the individual taking that job. An individual should give careful consideration to his particular lifestyle and preferences when considering any job offer.

Another important factor to consider in evaluating a job offer is the element of challenge associated with the prospective job. Challenge is an important ingredient in any job; perhaps the greatest single source of dissatisfaction among recently hired engineers has proven to be boredom and a sense of unimportance of the assigned duties associated with his beginning work in the field of engineering. In some instances, this boredom is the result of the reluctance of employers to entrust new engineers with important decisions; as a

result, recent graduates sometimes are given routine or simple tasks which involve no important decision-making. The boredom and sense of frustration which can result from such routine assignments are very important; they can stifle an individual's creativity and perhaps even ruin his career unless he recognizes this danger and seeks employment in a more challenging position. It is important, in evaluating job offers, to attempt to determine the responsibilities and duties which will be assigned to a particular job position and to determine if those responsibilities constitute a sufficient challenge to the individual's capabilities.

Opportunities for Women and Minority Groups

In the past, members of minority groups have been led to believe that they would be the victims of tokenism in seeking employment as engineers. In other words, they have been told that they will be given jobs in various agencies or corporations merely so that those agencies or corporations will have a minimum number of minority group members. This situation may exist in some areas but certainly does not exist at the present time in the field of civil engineering. Women and members of other minority groups should be encouraged to actively seek positions in which their capabilities will be utilized to the fullest; they should seek the greatest professional challenge available to them in prospective job offers. Members of minority groups are finding increasing opportunities for interesting and challenging employment in careers as civil engineers.

Several reasons can be cited to account for the increasing availability of challenging job opportunities for women and members of racial minority groups. Obviously, the civil rights movement which created sweeping social changes in the United States, in the decade of the 1960's, had great effects in the field of engineering as it did in other professions. Not only were professional organizations such as the National Society of Professional Engineers and the American Society of Civil Engineers made aware of the lack of equal opportunities for members of racial minorities, but engineering educators also were urged to exert greater efforts to recruit students from racial minorities. As a consequence, professional organizations and educa-

tional institutions have undertaken comprehensive programs to recruit members of all minority groups.

Women are finding increasingly important opportunities in civil engineering careers as a result of the changes in the attitudes on the part of both engineers and employers, which have occurred as a result of the civil rights movements and the movement for equal opportunity for women. At the same time, the work of the civil engineer has changed significantly in the last 50 years. Many activities which formerly were carried out by civil engineers in the field, in the mine, or in the quarry have been relocated to more pleasant surroundings. The percentages of civil engineers engaged in planning and design activities has increased in comparison to the number of civil engineers engaged in construction supervision and similar field work. A woman is no longer at a disadvantage in civil engineering activities, as she was in the past, when her job was likely to take her into uncomfortable, if not hazardous, situations. Of course, the increase in job safety and the decrease in hazards on the job also has been experienced by male members of the civil engineering profession as a result of the passage of comprehensive legislation designed to insure the safety of professional as well as non-professional workers in all occupations. Finally, women are finding that many of the stereotypes that they themselves had pictured as members of the civil engineering profession simply do not exist. Any woman with an aptitude for science and mathematics, and an interest in planning, designing and constructing physical facilities can find significant challenge and great rewards in civil engineering.

Today, an individual's performance is the most important basis for his evaluation by his colleagues and by his employers in the field of civil engineering. Sex, skin color, and religious beliefs no longer can be considered handicaps, or advantages, in gaining greater rewards and better jobs in the engineering profession. A civil engineer will be judged almost entirely on the basis of his or her solutions to technical problems and his or her ability to communicate these solutions to co-workers, clients, and the general public.

Employers' Attitudes

Another important consideration in evaluating any job offer is the attitude of the prospective employer toward the profession of civil engineering. Many employers, including consulting firms, governmental agencies and large corporations, have demonstrated great support and respect for professional employees for many years. Such employers encourage the new employee in the development of his capabilities; the development of professional attitudes among the technical staff in such organizations is the hallmark of a responsible employer. Other organizations and agencies may not adhere to such practices.

In evaluating a potential job opportunity, the recent graduate or the civil engineer seeking a change of employment should determine whether or not the prospective employer will provide a satisfactory climate for his professional development. Such a favorable climate is created if the employer supports professional organizations and societies for engineers, such as the National Society of Professional Engineers and the American Society of Civil Engineers. The new graduate should attempt to determine if new employees are encouraged to attend meetings and conventions of technical societies and professional civil engineering groups. He should ask if the expenses incurred by employees attending such meetings will be wholly or partially met by the prospective employer. He should inquire if an employee can be an active member of committees or technical groups within a professional organization such as the American Society of Civil Engineers.

If the recent graduate obtains negative answers to the inquiries listed above, and feels that employment with a particular company or agency will place him in an unprofessional atmosphere, he should consider employment elsewhere. This lack of professional attitude toward engineering employees will probably be a detrimental factor in the personal and professional development of the firm's employees. This detrimental effect far outweighs other advantages such as high salary, excellent fringe benefits or long vacations. The opportunities for professional fulfillment and advancement to more re-

sponsible positions are much more important than financial rewards in one's career as a civil engineer.

Educational Opportunities

The student in civil engineering who is completing a four-year or a five-year program may approach his graduation with the feeling that his education is now complete. Nothing could be further from the truth! This feeling would be appropriate only for a person totally lacking in pride and ambition. The conscientious and ambitious civil engineer will attempt to learn something new every day he or she is on the job. However, with the ever-increasing complexity of the field of civil engineering, it is no longer possible to be well-informed even about a particular specialty such as structural engineering or geotechnical engineering merely through an individual's own efforts or through job experience. The new civil engineering graduate will find that he will have great difficulty even reading all the monthly journals and magazines associated with the field of civil engineering. For this reason, it is necessary for the new civil engineer, and the experienced civil engineer as well, to be active in furthering his education. Continuing education can take several forms. The civil engineer may decide to participate in short courses or conferences which are held for several days in a particular location, usually on a university campus. On the other hand, he may choose to enroll in evening classes for an entire semester, in order to develop deeper expertise in a particular subject. In some cases, it may be possible for the engineer to obtain permission from his employer to attend college classes during the day. On the other hand, he may be restricted to attendance at one-day or two-day seminars and conferences. These conferences furnish important opportunities for the engineer to update his knowledge concerning specialized subjects. The opportunity to participate in these various forms of continuing education is an important asset in any job. In evaluating potential job opportunities, the new graduate or the unemployed civil engineer should carefully investigate the opportunities, in the offered position, for participation in continuing education programs.

Personal Development

Professional development through continuing education and the gaining of experience in civil engineering activities will not be sufficient for most individuals. Most civil engineers also will seek personal development through advancement to more responsible positions in their particular job assignments or in their company or organization. Obviously, advancement to positions of greater responsibility depends not only on the wishes and efforts of the individual, but also on the judgment of the individual's immediate superiors and on the policies of the organization or agency which employs the young engineer. In evaluating job opportunities, it is important for the civil engineer to carefully evaluate the opportunities for professional advancement in his proposed place of work. He should examine the organizational structure of a potential employer in order to determine whether or not it is possible to advance to more responsible positions after he has gained experience and/or participated in further educational efforts, and if possible he should try to estimate how rapidly he may advance to positions of more responsibility.

Greater responsibility in a job assignment can take a variety of forms. The young engineer may be given the chance to work with greater numbers of his colleagues, or with a larger labor force if he is engaged in the supervision of construction activities. On the other hand, if he is working in a design office, he may be given the responsibility to plan and design more complex or important structures or systems. He may be given the opportunity to advance professionally by entering the field of management. If he succeeds in any of these opportunities to demonstrate his increased capabilities, his personal advancement will be recognized by promotion to a higher grade or to a more responsible official position with a corresponding increase in salary and other benefits. In many large organizations such as federal governmental agencies, salary increases are given to engineers automatically with seniority at particular grade levels. Promotion to a higher grade level will come with increased experience on the job and with the demonstration of an individual's capability to manage more complex systems or to solve more difficult technical

problems. Promotion to a higher grade level in a federal agency or organization allows the individual to earn a new series of raises in salary and fringe benefits associated with that higher grade level, increasing seniority, and satisfactory performance of assigned duties.

In other organizations, such as consulting firms, increases in salary and benefits may not come automatically with seniority. However, an individual may have a greater opportunity to advance rapidly to senior engineering or management positions in these smaller firms. Nevertheless, in almost every organization, the civil engineer's advancement will be directly dependent upon the quality and quantity of the effort he or she expends on the job. In examining job offers, the new civil engineering graduate or the unemployed civil engineer should try to evaluate the potential for returns in the form of more responsibility and higher salary which he or she is likely to receive for his investment of time and effort.

Salaries and Fringe Benefits

The most obvious factor in evaluating a potential job opportunity in civil engineering is the salary and fringe benefit package which is being offered by the prospective employer. It is usually easy to compare the one job offer with another on the basis of the salaries and fringe benefits associated with each position. Salaries and fringe benefits are the most obvious attractions for any potential employment. However, in the long run, these factors are not nearly as important as the factors mentioned in the previous sections, such as personal interests and the possibilities for professional and personal development. On the other hand, salaries, fringe benefits, job security and working conditions should be considered. Starting salaries for civil engineering graduates today should not be a major factor in the evaluation of job offers since the differences between starting salaries from one organization to another tend to be quite small and generally are balanced by differences in the fringe benefits offered by one employer as compared to those of another. Furthermore, differences in starting salaries usually disappear after several years of employment with a given organization. In other words, two individuals hired at slightly different starting salaries generally tend to

reach the same level of income in a specific organization, if they have displayed equal capability and perseverance. The salary ranges which have been listed in previous chapters in this book indicate that, in any event, starting salaries for recent civil engineering graduates are likely to be higher than those of graduates in many other professional fields.

Fringe benefits differ from salary in that fringe benefits usually are more important to employees with dependents, or with other circumstances which create special needs. A married engineer with a family may look more favorably on a job offer which includes payment of travel expenses incurred during the movement of his family and belongings to the new place of employment, as compared to a job offer which does not include such a benefit. The health care and medical insurance provisions offered by a prospective employer are extremely important to married engineers with children, to persons with health problems, and to those who must support dependents with potential health problems. These factors are relatively unimportant to healthy, young, single college graduates. Obviously, the importance of health care and insurance benefits, as well as other benefits will have varying degrees of importance to different individuals depending upon those individuals' particular circumstances. These benefits, however, must be evaluated carefully because they may have very great long-term significance.

Other benefits associated with employment as a civil engineer include unemployment insurance, and social security retirement income. Almost all job assignments for civil engineers in the United States today will be covered by social security. Social security payments guarantee the engineer a retirement income. In almost all large engineering and technical organizations, supplementary retirement or annuity plans are available for all employees. The civil engineer considering a job offer should evaluate the benefits package available from a prospective employer, particularly with respect to the cost sharing furnished by that employer on retirement plan payments.

Job Security

As mentioned previously, job security in a career as a civil engineer today is relatively good. There has been, and should be, a continuing stable demand for civil engineers in today's industrial society. Nevertheless, job security will vary somewhat depending upon the civil engineer's particular area of specialization, and depending upon the type of employment he has secured. For example, the civil engineer employed by a federal government agency will be protected by the provisions of the federal civil service regulations. Although in some instances the civil engineer cannot gain employment in such an agency without passing a competitive examination, he is protected against arbitrary unemployment by this system. He is virtually guaranteed of subsequent promotions and raises in grade if his performance is satisfactory and his progress agrees with the well-established procedures for promotion in his particular agency. A civil engineer will be discharged from a civil service position only if he or she is an unsatisfactory worker or is guilty of illegal or immoral conduct. Consequently, employment in a federal agency, or in state and local agencies covered by civil service regulations, carries a great measure of job security.

On the other hand, employment in private civil engineering firms is somewhat more subject to economic fluctuations and the success of the particular private venture. Permanency of employment varies with the size and stability of the company or organization. In general, engineering organizations tend to be stable employers; however, civil engineers who are employed in organizations which are closely related to industrial production or to a particular facet of the economy, such as defense spending, may face the possibility of temporary or permanent lay-offs. Employment tends to be least stable in very small organizations. The civil engineer who is self-employed as a consulting engineer obviously has no guarantee of employment since he depends upon individual client-consultant agreements. Consultants experience a certain fluctuation in demand in that at times they find they are offered more work than they can possibly accomplish, while at other times they are idle for short periods, waiting to be contacted by clients. Against these dangers of possible

unemployment, the self-employed consultant can count on one advantage; he is his own boss. He establishes his own salary and his own retirement age. He is responsible for securing his own retirement compensation through financing an annuity or a similar retirement plan. This is an added responsibility and risk in self-employment. The civil engineer must weigh all of these possible advantages and disadvantages carefully before he embarks on a career as a self-employed consultant, or before he becomes associated with a relatively small consulting firm.

GETTING STARTED

As mentioned in the paragraphs above, because of the relatively constant demand for civil engineering graduates today, the prospective graduate of a civil engineering program is likely to be approached by many prospective employers. In most cases, these employers are brought into contact with the students through a college placement bureau. Most universities and technical institutes with civil engineering curricula have placement bureaus which assist the new graduate in obtaining employment. Generally, these placement bureaus also assist former students, who may be temporarily unemployed, to find new jobs. In schools where cooperative education programs are featured, the employment or placement bureau usually will be responsible for finding appropriate jobs for engineering students during their tenure in school. The main activity of these placement bureaus, however, is to insure contact for new graduates with prospective employers, including federal agencies, industrial firms, consulting engineering organizations, and other technical employers. Representatives of these organizations ordinarily will visit the college or institute campus to interview interested prospective graduates. To get permission to do this, these representatives must first describe the job openings and opportunities available in their respective organizations and secure permission to interview students from the director and staff of the college placement bureau. The director of the placement bureau will be well-informed concerning the qualifications and desires of the new engineering graduate; he

will evaluate the employment opportunities offered by various organizations before the representatives of those organizations visit the campus to recruit the new graduates. The placement bureau of a college or university can be relied upon by the prospective graduate to direct him to employers who will offer positions appropriate to his talents, desires and educational background in engineering. This placement service is a part of the function of the college or university, and neither the student nor the prospective employer pays any fee to the institution for this service. Almost all recent graduates from civil engineering programs find employment through college placement bureaus.

However, a limited number of graduates may wish to find employment through private employment agencies. These outside employment agencies exact a fee from either the student or the prospective employer for arranging the interviews between the graduate and employer which lead to the subsequent employment. Also, state-controlled public employment agencies generally have offices in large urban areas and small branch offices in rural communities. These employment agencies in general are set up primarily to assist unskilled and semi-skilled workers in seeking jobs with industrial firms and other organizations. Generally, the civil engineer will not find it necessary to utilize a public employment agency; however, if he does so, he will find that there will be no charge for any services rendered. Private employment agencies are operated to make a profit, and their income is derived from the fees which are charged to the job applicant seeking employment and/or the employer seeking a new employee. In general, these fees are established in proportion to the starting salary paid to the new employee.

Some new engineering graduates, and civil engineers with some experience who wish to change jobs, may want to make direct contact with prospective employers. These individuals will be greatly assisted by examining the advertisements carried in many of the professional technical journals, such as *Civil Engineering*, the official publication of the American Society of Civil Engineers. This journal and other similar journals such as the *Engineering News - Record*, carry ads for "positions available" to prospective employees, and "positions wanted" in civil engineering by engineers wanting a

change in their present employment. The unemployed civil engineer may also utilize the publications of the major engineering organizations listed in Appendix A to find advertisements from prospective employers, describing jobs and available positions. If the engineer wishes to be extremely selective in obtaining new employment, he may decide to advertise in one of these publications, describing the type of job he wants and listing his qualifications and capabilities. Job opportunities are also described in regional trade journals, newspapers, and other publications, particularly in instances where large public works projects must be carried out in a particular locality, and a sudden significant demand for engineering talent is created there.

If the new graduate or the unemployed civil engineer finds an advertisement for a job which appeals to him and appears to be worthwhile, he must establish contact with the prospective employer. In most cases, the traditional response to an advertisement in a journal or in a newspaper is the submission of a written résumé which lists the individual's experience and educational attainments.

Résumés

A written résumé of personal experience and employment history is an important tool for the civil engineer seeking new employment. A comprehensive résumé also may be valuable to the civil engineer who stays with one organization throughout his entire working life and at no time seeks employment elsewhere. The résumé will be useful to the civil engineer, and to his employer, for purposes of demonstrating and verifying his or her capabilities and experience. For this reason, experienced civil engineers devote considerable time and attention to the preparation of a comprehensive written professional résumé.

A résumé is basically a statement of an engineer's personal history and experience. Ideally, a good résumé is a very useful document, since it permits a number of people, including prospective employers, to review an applicant's record without the necessity of a personal interview. A particular individual may not be suitable for a certain job position, even though he or she has no particular faults or shortcomings in experience, education, or technical background.

A job interview in such a case could lead to considerable unnecessary consumption of time and possible embarrassment for both the prospective employer and the job applicant. In such cases, where the job requirements are not suited to the applicant's background, examination of a written résumé many times will determine that a personal interview is unnecessary.

The civil engineer may be called upon to prepare one of a variety of different types of résumés. These résumés may include such standardized forms as college interview forms, governmental agency forms, and standard employment forms for major industrial organizations. The college interview form has been standardized to a great extent by the various colleges and universities which offer programs in engineering. Usually, this form is completed by the student and submitted to the college placement office early in the last year before graduation. The placement director for the school then tries to match the student's interests and capabilities with the needs and desires of prospective employers to arrange interviews for the student with employers who are offering jobs appropriate to his interests and abilities.

Federal government forms are highly standardized and are designed to illustrate the job experience of the applicant. These forms can be secured from the Civil Service Commission in Washington, D.C., or in almost any branch office of a major federal agency throughout the country. State governments and certain federal agencies may have special résumé forms because of the special needs of those particular organizations. In the same way, major industrial organizations or engineering concerns may have standardized employment application forms. These forms can be obtained from the personnel office or employment office of the particular company or organization involved. If the civil engineering graduate or the experienced civil engineer is seeking employment with an organization which does not furnish a standardized résumé form, the individual may choose to prepare his own résumé. If this is the case, the following comments should prove to be helpful. The professional résumé should be as brief and concise as possible without eliminating any useful information. The résumé should be accompanied by a type-written cover letter which explains to the prospective employer why

the résumé and application for employment are being submitted. It is important that the applicant prepare a neat and attractive résumé; the first impression that the prospective employer will form concerning the applicant will be generated by the cover letter and the résumé.

A review of a number of résumé forms utilized by governmental agencies, industrial organizations, engineering firms, and self-employed consultants shows that these forms do follow a somewhat standardized format. Generally, written résumé give the data in a straightforward sequence, usually a time sequence, although the order in which the items are presented may vary somewhat from one form to the next. In most cases, the listing of data on a résumé begins with personal data such as the name, address, and telephone number (both home and business numbers) of the applicant. Next, the applicant's birth place, birth date, and sex are listed. Usually, in this section of the résumé, the applicant's marital status and medical history particulars are given. The applicant should list his Social Security number in this section of his résumé. He should be careful to describe the details of any major physical handicaps or disabilities, although long and detailed descriptions of particular illnesses should be avoided. Such descriptions, in general, would be useless since most employers will usually insist that the applicant be given a physical examination before he is hired.

The next item on most résumé forms is a complete description of the applicant's educational background. His high school and college experience are listed, with the number of years completed in each particular school. The addresses of all schools attended may be given; professional engineers also may wish to include schools where they have attended short courses or seminars on special topics in order to indicate their particular expertise in these topics. The applicant customarily lists all certificates and degrees earned, giving the title of the degree, the year awarded, and the institution awarding the degree. The civil engineer should list not only his major field, civil engineering, but should indicate any possible minors in associated branches of engineering and science, and should indicate pertinent areas of specialization. He should give his overall grade point average at each institution he has attended. A transcript of the civil

engineer's educational record may not always be required for every job application, but a transcript is a valuable enclosure in an application to a prospective employer, particularly if the applicant has an outstanding academic record. Usually, in most written résumés, the applicant lists his standing in his graduating class, by listing the quarter of the class in which he or she was placed. It is important that the applicant remember to list all continuing educational efforts he has made including attendance at evening classes and short courses. Also, in this section of the standard written résumé, the applicant will usually give a brief description of any extracurricular activities in which he engaged during his college years, including class offices held, athletic participation, academic honors and recognition, and other activities associated with his college life.

With respect to the résumé, the job applicant should list information concerning his or her military record, including present military classifications and the prospects for any active or reserve duty. The applicant may be required to, or he may wish to give information concerning any past arrests. It is advisable for the applicant to disclose such information voluntarily, since most employers who are not furnished this information by the applicant may form an undesirable impression of the individual if such a record is revealed at a later date.

Most written résumé forms, including those initiated by the job applicant himself, include information concerning membership in professional and technical societies. The applicant should list any service as an officer or member of committees within such organizations. Also, he should list any memberships in honorary or scholastic organizations such as Tau Beta Pi, the national honor fraternity for engineering students. If appropriate, the job applicant will list professional licenses or certificates which he or she has been granted and the dates such licenses originally were issued. Any honors, awards, or prizes for outstanding achievements in technical or professional activities during college or during previous work assignments should be included in the résumé.

For civil engineers with some experience who are seeking new employment, a list of technical and professional papers and articles written by the applicant should be furnished on the résumé. The

experienced applicant should list civic and social activities of any significance, such as participation in church organizations, community agencies, charitable organizations, and other civic activities undertaken for public benefit. The most important part of the résumé for the experienced civil engineer, who is seeking a change of jobs, is a complete description of his entire work experience record. Obviously, for the graduating student, this portion of the résumé may contain only cooperative work assignments or summer work in which he has been engaged. However, the experienced engineer should list all positions held during every year from the date of his graduation up to the present time. If there are any gaps in this employment record, they should be explained. The experienced civil engineer need not describe technical experience gained during college or before his college enrollment. It is more important for the experienced engineer to describe, in considerable detail, each successive employment position he has occupied since his graduation. He should list the duration of his employment by month and year and give a full description of the duties performed on each job. The starting and finishing salaries for each job may be given if the applicant desires, and the name and address of the applicant's immediate supervisor for each assignment may be listed. In each case, the name and address of the employer should be given, along with the reason for the change of employment. For the most recent employment period in the career of the experienced engineer, the duties performed and the work accomplished should be described in detail. The prospective employer obviously will read this information with considerable attention and interest. The applicant should state clearly what his responsibilities were on each particular assignment, and the results of his efforts in each particular task. The engineer should not hesitate to describe any praise-worthy achievements. If a particular assignment was accomplished in a noteworthy manner with exceptional success, mention should be made of this fact. However, the applicant should be careful not to exaggerate the circumstances of his successes, but should only state the facts concerning his performance.

Almost all standardized résumés include a space in which the applicant is asked to supply the names and addresses of at least three

or more professional or personal references. The civil engineer preparing his own written résumé also should give such references. The references should be persons who know the applicant sufficiently well to be able to comment knowledgeably on his or her capabilities, attitude, character, and personal reputation.

If the résumé is prepared well, be it a standardized form or a self-initiated effort, and if it is attractive to a prospective employer, the job applicant will be well rewarded for the effort and time he takes in carefully preparing the data. In most cases, if a prospective employer is interested in the applicant, after his review of a written résumé form, he will establish contact with the applicant and indicate a desire for a personal interview.

Personal Interview

The personal interview is a crucial step in the employment process for any engineer. For recent graduates, the personal interview may be the cause of considerable anxiety and concern. This interview need not be an occasion for anxiety; on the contrary, it should be an interesting and educational experience for both the job applicant and the prospective employer.

The job applicant should always remember that any interview is essentially a conversation between two people—the representative of the prospective employer and the applicant himself. If an engineer is being interviewed for a job in a governmental agency or a large corporation, it is quite likely that the interviewer will be a professional personnel specialist who is regularly employed in recruiting new technical employees. These representatives maintain continuous contact with the colleges and universities offering programs in civil engineering. The interviewer may well be a civil engineer or a technically-trained individual who is interested in personnel management, or he or she may be a personnel specialist without any extensive technical background. In any case, the applicant should always remember that the interviewer has been judged to be qualified to represent the prospective employer. Almost certainly, the interviewer will be well-informed concerning the capabilities and needs of the organization he or she represents. Finally, the applicant

should remember that the interviewer has been trained to evaluate prospective employees.

In most cases, at some time shortly before graduation, the prospective new civil engineer is brought together with an interviewer by the personnel of the college placement office. The time and place of the interview will be determined by the placement office in agreement with the representative of the employer. The placement office will usually publish notices concerning the times and places at which representatives of various employers will be present to conduct interviews. The prospective graduate can then register with the placement bureau for any interview in which he has an interest. Usually, the prospective employers will have furnished the placement bureau literature concerning their operations and requirements; the applicant should obtain such literature and study it carefully. Then, he should make a list of questions which are not answered in the information furnished by the employer.

Interviewers attempt to maximize their efforts when they visit college campuses. Consequently, their schedules are likely to be full and rather inflexible. For this reason, the applicant should be sure to arrive on time for the interview. Tardiness for a job interview may create an unfavorable impression in the mind of the interviewer and may lead to the loss of a desirable job offer. In coming to an interview, the applicant should be sure to dress appropriately; in other words, formal dress is not required, but extremely casual or sloppy dress should be avoided. During the actual interview session, the applicant should allow the interviewer to guide and direct the flow of questions and the discussion. In almost all cases, the interviewer will have a list of routine questions he will wish to ask all job applicants. In general, these questions will probe the engineer's interest in the work of the prospective employer, the educational courses or job experiences that were most rewarding to the engineer, and the engineer's desires and ambitions in regard to future work. The applicant should try to respond to the interviewer's questions in a careful and concise fashion, being careful not to wander into discussions of unrelated topics.

The interviewer usually will give the applicant engineer an opportunity to ask questions; however, if the time for the interview is

drawing to a close and such an opportunity has not been given, the applicant should interrupt the discussion in order to ask any important questions he may have concerning employment or living conditions at the place of the proposed employment. In all cases, before the interview is at an end, the applicant should be sure that he completely understands all of the conditions of employment involved in a particular job offer. In some instances, he may be offered a job at the conclusion of a single interview; in other instances, the first interview may lead only to a succession of further meetings. Additional meetings may lead to inspection trips on the part of the applicant engineer. During these trips, the young engineer should be careful to remember that the treatment he receives during an inspection trip or plant visit may not be the same treatment he will receive as a regular employee. The engineer should be careful to establish a good impression in the minds of his prospective employers by prudent and careful conduct during inspection trips. It is important to remember that during such trips, not only is the applicant inspecting the prospective place of employment, but also he is being inspected by his prospective employers.

Evaluating Job Offers

After the new graduate has gone through a series of interviews and has received a number of job offers, he will be faced with the difficult decision of choosing the right job. In evaluating various job offers, he should review the factors listed in the first sections of this chapter. If possible, the applicant should discuss the offers with experienced friends or with colleagues at his place of business, or with members of the faculty at his school.

When the engineer finally has decided to accept a particular offer, he should advise the selected employer immediately and should inform the college placement bureau or employment agency involved. At the same time, he should be sure to notify all other employers who have offered him positions that he is electing to accept another offer. It is not necessary for the applicant to disclose which offer he has accepted unless he wishes to do so. Under no circumstances should the applicant attempt to play-off one employer

against another to get a more generous salary or fringe benefits package. Such a maneuver is likely to result in all job offers being withdrawn.

THE PATH TO ADVANCEMENT

After graduation from a civil engineering curriculum, some individuals will obtain employment with a particular organization or agency and remain with that organization throughout their entire professional careers. On the other hand, other individuals will seek several changes in employment during their careers for personal or professional reasons. In either case, as an ambitious and conscientious civil engineer, the young man or woman entering the field of civil engineering should seek to advance professionally and personally. The path to advancement can have several different branches. The civil engineer may move on to positions of greater responsibility in technical activities, or he may go into positions of responsibility in supervisory activities and management.

Technical Specialization

In general, new civil engineering graduates initially will be employed to fulfill a basic technical position with an engineering firm or agency. The title they are given may be "junior engineer," "basic engineer," or simply "engineer." If the engineer has graduated with an advanced degree, he may be employed at the next level up the ladder of professional advancement with a title such as "assistant" or "associate" engineer. The successful engineer moves along a path of professional advancement to the point where he must select a career as a technical specialist, as a general practitioner, or as a manager. Usually he faces this choice at the level where he is called a "senior engineer" or a "resident engineer." In planning and design offices, the "senior engineer" generally is responsible for coordinating the work of a small number of junior and assistant engineers and auxiliary personnel such as technicians and draftsmen. The "resident engineer" usually is employed in construction to supervise the com-

pletion of a segment of a construction job rather than the entire job itself.

If the senior or resident engineer elects to advance professionally by becoming a technical specialist, he may be given a title such as engineering specialist or principal engineer. He may become a consultant to the general practitioners and management personnel within a given agency or organization. In general, the person who elects to become a technical specialist is the person who feels that he may not have the capabilities to be an effective manager or one who is unwilling to relinquish his technical work for the increasing responsibilities in supervising and managing the work of other engineers.

The general practitioner may follow a somewhat different path for professional development. He may rise from the level of senior design engineer or resident engineer to general engineer. In essence, his advancement up the ladder of professional development entails the need for supervising the work of an increasing number of subordinates. He must undertake more administrative work such as the preparation of reports on the activities of his subordinates and must schedule individual workloads. Additionally, he may be involved in developing schedules and budgets for the work he supervises. In general, he is given a title such as "general project engineer" or "general design engineer" and rises to "principal engineer" or "principal project engineer." In consulting organizations, he may rise to a position as an associate of the firm, and then may assume more comprehensive administration duties as a vice-president or a partner in the organization.

As mentioned in an earlier chapter, some individuals decide to forego direct technical activity in engineering for the challenge of management activities. Usually, this step is made at the level of senior or resident engineer. At this point, a civil engineer electing a career in management assumes more responsibility for coordinating and arranging the activities of a group of his colleagues. He is engaged more and more frequently in making decisions on non-technical matters involving the allocation of personnel to specific tasks or in choosing objectives for his particular organization. He may assume successive titles such as "engineering supervisor," "engineering superintendent," "branch chief," "engineering manager," or

"division chief." If he reaches the executive level of management, he may have a title such as "director" or "president."

Advancement along any one of these various paths is dependent primarily on the individual's interest in his job and his perseverance in accomplishing his job duties. In organizations where a civil service system governs promotions and advancement, employees will be promoted on the basis of their technical expertise and achievements as well as their accumulated seniority. Their ability to accept more complex and demanding tasks and to carry out those tasks successfully also will be taken into account. In some organizations, the employee must take examinations to qualify for promotion. In other firms or agencies, a board of experienced senior engineers will review an employee's credentials and his work experience and recommend action relative to possible promotion. In organizations without civil service guarantees, generally a somewhat parallel or similar administrative procedure will have been established to show the employee what he must do to achieve promotion and advancement. Obviously, in small firms, and especially in consulting organizations, promotion and advancement may be dependent upon the opinion of one or two senior individuals such as the president or owner of the consulting firm. In any case, the most important requirements for advancement in the profession of civil engineering are a demonstration of technical competence and a willingness to spend the required time and effort necessary to accomplish assigned tasks and responsibilities. In a career field such as civil engineering, there is no substitute for hard work. However, an individual may find great encouragement through the establishment of close contacts with his fellow engineers, not only in his own place of employment, but in other agencies and organizations, through membership in professional organizations and societies. Memberships in such organizations can be very effective in broadening the professional development of the young engineer and presenting the experienced engineer with more opportunities for the exercise of his talents and capabilities. Such organizations are described in Chapter 6.

CHAPTER 6

PROFESSIONAL ORGANIZATIONS IN CIVIL ENGINEERING

Various organizations exist through which the reader can discover more about careers in engineering. Nearly 200 engineering or related societies are listed in the Directory of the Engineers Joint Council. The services of many of these organizations are available to both high school and college students, as well as to practicing engineers. Some of these organizations are open for membership to all engineers without regard to their area of professional specialization, while others, such as the American Society of Civil Engineers, are for members who practice a particular type of engineering. During college, a student can join a number of honorary, social, and professional organizations affiliated and involved with civil engineering. A graduate engineer can become registered to formally recognize his or her capabilities as a practicing professional engineer, and he or she can become a member of one or more of the professional organizations specifically formed for civil engineers.

Organizations in High School: Science Clubs and Junior Engineering Societies

Many American engineering societies exist for the basic purpose of disseminating information. Among the numerous types of information available from these societies, including the American Society of Civil Engineers, is guidance material for high school students considering a career in engineering. High school students can obtain this information concerning engineering careers from their counselors or teachers or from local representatives or members of the

professional societies. The National Society of Professional Engineers is quite deeply involved in career orientation programs specifically directed toward high school students. Representatives of this society regularly conduct orientation programs in many cities and towns in the United States. In such programs, high school students visit engineering, industrial, and technical organizations and see engineers and technologists at work. In these programs, students are given ample opportunity to investigate the work of the engineers as well as to meet and talk with practicing engineers. Interested students or counselors should contact the local chapter of the National society of Professional Engineers for further information about such programs in their localities.

In addition to the orientation programs conducted by the National Society of Professional Engineers, a separate program, the *Junior Engineering Technical Society* (JETS), also exists for the purpose of furnishing information to high school students who are interested in careers in engineering. This organization was founded in 1950 to sponsor extracurricular programs for high school students in both rural and urban areas. One of its primary activities is the sponsorship of JETS chapters in junior and senior high schools. These chapters, in turn, sponsor extracurricular clubs under the supervision of a faculty advisor assisted by a volunteer professional engineer from the community.

The typical JETS chapter or club holds regular meetings at which members explore various aspects of the fields of engineering. The club may visit local industries, consulting firms, and government agencies to discuss their interests with engineers and scientists in practice. Programs, projects, and other group activities are part of most clubs' programs. Information concerning membership can be obtained from any local chapter of that organization or from the JETS National Office, 345 East 47th Street, New York, New York 10017. JETS chapters have been formed in many cities and towns in the United States and have proven to be a very worthwhile means to acquaint high school students with the career opportunities in Civil Engineering.

In addition to the high school clubs and programs sponsored by engineering societies, there are many other science and mathematics

clubs that the prospective civil engineering student will find educational as well as enjoyable. These clubs frequently have programs and speakers that are valuable sources of information for young people who are trying to choose a career.

College Professional and Social Organizations

Students in a civil engineering curriculum at a university or college can become members of several different organizations associated with their particular field or study. Almost all of the national engineering societies, including the American Society of Civil Engineers, have student chapters in colleges and universities throughout the United States. The student chapter of ASCE on the campus will be sponsored by a local section of the national organization. In addition to the very interesting programs and field trips that the student chapter officers will arrange for chapter members, the students frequently will be invited to participate in the activities of the local section. These activities will include programs with prominent engineering speakers and tours behind the scenes of outstanding civil engineering projects in the area.

The National Society of Professional Engineers (NSPE) also sponsors student chapters in many engineering schools. These clubs are open to students from all branches of engineering and will have programs of interest to all engineering undergraduates.

The civil engineering student may be invited to become a member of Chi Epsilon, an undergraduate honor society for outstanding civil engineering students. Chapters of Chi Epsilon are found at many universities. The civil engineering student may be invited, as an outstanding scholar, to become a member of Tau Beta Pi, the national honorary engineering society. Election to Tau Beta Pi, for an engineer, is equivalent to election to Phi Beta Kappa for a scholar in the arts and sciences. Members, both male and female, are chosen for this society on the basis of outstanding potential as a member of the profession of engineering, as well as on their performance as undergraduate students.

In addition to these honorary and professional organizations, there are many social and service organizations on every campus

which are open to civil engineering students. The prospective engineer would do well to consider joining one or more of these organizations in order to gain social contact with students from many diverse backgrounds, interests, and fields of study. Among these groups are the Greek fraternities and sororities, religious clubs, military veteran groups, political clubs, and the many types of musical associations open to student members.

For members of minority groups and for women, special organizations have been formed to fulfill identified needs. Women interested in careers in engineering or who already are practicing in the field can become members of the Society of Women Engineers. Information on this society is available to interested individuals from the Society at the United Engineering Center, 345 East 47th Street, New York, New York 10017. In addition to this organization for women, a number of other organizations have been formed to respond to the needs of various ethnic and racial groups whose members practice in the field of engineering.

Professional Licensing and Registration

Of all engineering professionals, the civil engineer deals more directly with, and is more responsible for, maintaining public health and safety than any other type of engineer. For this reason, it is important that there be laws requiring the examination of the qualifications of civil engineers before they are permitted to practice in capacities where public safety is their concern. All fifty states and the District of Columbia currently have laws requiring the licensing or registration of all professional engineers, including civil engineers. These laws require that members of registration boards, established for this purpose by the various state legislatures, secure evidence of education and experience for each applicant, and determine whether or not the applicant fully understands the basic principles of science and technology necessary for the safe practice of engineering in that particular state. While the requirements in each state differ, in accordance with the specific law of each state, registration is normally granted only after a one- or two-day comprehensive examination.

The primary justification for registration and licensing of engi-

neers is protection of the public. The requirement for licensing was well stated some years ago by the judge of a Utah court in the case of *Clayton v. Bennett* (298 P. 2d 531) as follows:

It has been recognized since time immemorial that there are some professions and occupations which require special skill, learning, and experience with respect to which the public ordinarily does not have sufficient knowledge to determine the qualifications of the practitioner. The layman should be able to request such services with some degree of assurance that those holding themselves out to perform them are qualified to do so. For the purpose of protecting the health, safety, and welfare of its citizens, it is within the police power of the State to establish reasonable standards to be complied with as a prerequisite to engaging in such pursuits.

In this regard, it is recommended that all civil engineering graduates become registered as soon as possible after graduation. There are various reasons for this recommendation; however, the two most compelling reasons are: 1) courts of law generally do not recognize a person as an engineer unless that person is registered (this can be a serious obstacle should the person ever wish to testify as an expert witness); and, 2) while the activity that an engineer is currently engaged in may not require registration, it is probable that at some point in his career he may wish to change to a position in which registration is required.

As pointed out previously, each state has its own specific registration law. However, the most common requirement for registration at the present time is the successful completion of two one-day comprehensive examinations. The first day's examination usually covers the basic fundamentals of engineering as taught in an ECPD-accredited curriculum. Many states permit this first examination to be taken just prior to, or immediately after, graduation. When a candidate successfully passes this examination, he or she is granted a certificate designating him as an Engineer-In-Training (EIT). The second examination may be taken only after the applicant fulfills the particular state requirement for minimum number of years of practi-

cal experience. Upon completion of this second requirement (x years of experience plus the second examination), the graduate engineer is registered and granted a license to practice engineering in that state.

Once registration is granted, further examination presently is not required. However, several state registration boards currently are considering the adoption of a requirement that periodically an engineer may be required to show proof of some degree of continuing engineering education, before renewal of the engineer's license. These requirements, if adopted, will probably be similar to those now in existence for the medical and teaching professions.

Membership in Professional Societies

As previously stated, there are more than 200 engineering societies or related groups in the United States today. The graduate civil engineer will find that professionally it will be profitable and necessary for him to join several of these societies, including at least one devoted to the field of civil engineering. The primary purpose of most professional organizations is the exchange of information among its members, to their mutual benefit.

The American Society of Civil Engineers (ASCE) is the oldest engineering society in the United States. Among its objectives, as stated by the society itself, are:

1. To encourage and publicize discoveries and new techniques throughout the profession.
2. To afford professional associations and develop professional consciousness among civil engineering students.
3. To further research, design, and construction procedures in specialized fields of civil engineering.
4. To give special attention to the professional and economic aspects of the practice of engineering.
5. To enhance the standing of engineers.
6. To maintain and improve standards of engineering education.
7. To bring engineers together for the exchange of information and ideas.

The National Society of Professional Engineers (NSPE) has as its objective: "The promotion of the profession of engineering as a social and as an economic influence vital to the affairs of men and women of the United States." It is one of the largest societies in this country with membership open to all registered engineers. The NSPE maintains a Washington office and takes a very active interest in any national legislation that affects engineers or the profession of engineering.

There are other societies that the practicing civil engineer may also wish to affiliate with in order to associate with other engineers and professionals doing similar kinds of work. Among these latter types of societies would be such groups as the American Public Works Association, the American Water Works Association, the American Association of State Highway and Transportation Officials, the American Concrete Institute, and the Water Pollution Control Federation, etc.

Membership requirements will vary from society to society; however, many groups such as the ASCE have student membership grades from which the student may transfer to associate membership upon graduation. The primary reason for belonging to a society of any type is to participate in its activities, and to contribute to the exchange of professional information so vital to any profession's existence. Each prospective civil engineer is encouraged to investigate the student society memberships available to him while completing his undergraduate studies.

A FINAL WORD

In the preceding chapters, the field of civil engineering and all the wide range of activities and specialties within that field have been described. It was not possible to include all of the job assignments open to civil engineers, but a great many typical engineering activities have been described. Anyone interested in a career in civil engineering should have discovered from those descriptions that an opportunity exists today to work in a technical specialty branch within the general field of civil engineering for a more-than-adequate salary under very favorable working conditions. The preparation involved in a college curriculum in civil engineering, and, for that matter, a degree in civil engineering do not guarantee subsequent advancement in the field. However, civil engineers who are ambitious and persevere in their efforts almost surely will advance professionally and personally. The civil engineer's responsibilities and rewards will increase with his or her experience on the job, as indicated by the statistical data on duties and salaries presented in Chapters 4 and 5. Additionally, the ambitious civil engineer will find ample opportunities to move into related fields of engineering, or to advance into management positions supervising both technical and nontechnical personnel. A basic education and experience in civil engineering also can provide a foundation for a rewarding career in engineering sales. On the whole, a career in civil engineering offers great promise; however, it requires dedication and hard work, and possesses certain limitations.

For example, civil engineers deal principally with things rather than with people. An engineer analyzes and designs systems consisting of natural forces and material goods and does not deal principally with individuals or communities. Obviously, though, the civil engineer's activities have great impact on the welfare of both individuals

and communities. Nevertheless, the civil engineer relies on his background and education in physical and natural sciences, particularly mathematics, to solve technical problems in the real world. He is not interested in searching for absolute truths as is the scientist, nor does he deal with specific mechanics of problem solving as does the technician. Rather, he attempts to analyze general situations, develop and design systems to satisfy needs and solve problems, and to oversee and supervise the implementation of his designs.

In general, civil engineers are well-paid individuals. Engineering careers generally offer ample job security, with good salaries and fringe benefits for capable individuals. In comparison to other engineering specialities, average salaries for civil engineers are somewhat lower than in other branches such as electrical engineering and chemical engineering. However, employment opportunities in civil engineering are not subject to major fluctuations with economic conditions as are employment opportunities in other branches of engineering. Additionally, a small fraction of the total number of civil engineers find employment as consultants; when the civil engineer is self-employed in this fashion his hopes of attaining salaries much higher than the average are greatly enhanced. In any case, the civil engineer will be able to see the designs and solutions he has prepared implemented in concrete and steel, or in a similar material fashion, in many instances. This direct evidence of productive effort is one of the most rewarding features of a civil engineering career. If, on the other hand, you derive more satisfaction from dealing with the intangible personal problems of your fellow men, you may feel frustrated in working as an engineer where you must concentrate on material things rather than on people and personal relationships.

If you are considering a career in civil engineering, examine very carefully the material presented in the first and third chapters of this book which describe the functions of civil engineering and the technical specialties within the general field of civil engineering. Review the job duties, salaries and working conditions, and the general potential for advancement which are described in Chapters 4 and 5. If the activities described in this book seem attractive and appealing to you, and if you have a strong capability in mathematics and the physical sciences, it is quite likely that you will find great satisfaction

in a career as a civil engineer. If you feel that you have an inclination toward this field of endeavor, carefully review the material in Chapter 2 describing the education necessary for practice as a civil engineer. Be sure to establish the correct foundation for a college education in civil engineering by enrolling in the proper high school courses in mathematics and physical science. Carefully choose an accredited engineering school and explore all possible opportunities for financial assistance at that school. Extend your explorations to several schools if you choose. After you have made your choice, and have entered a university or college to pursue an education in civil engineering, carefully review your progress to date and be sure that you have made the correct career choice. If you remain satisfied and if you successfully complete your college education, we look forward to having you join us as colleagues in the great profession of civil engineering.

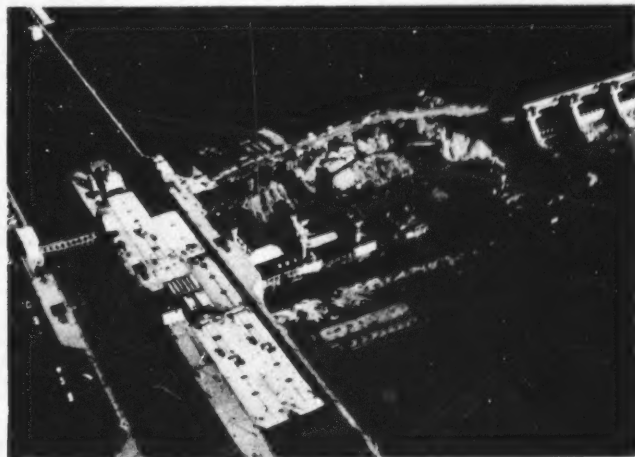


Photo: U.S. Army Corps of Engineers

Design and construction of this dam involved specialists in water resources, hydraulics, geotechnical engineering, structural engineering and construction management.

APPENDIX A
GENERAL TECHNICAL PUBLICATIONS

APWA Reporter

American Public Works
Association
1313 East 60th Street
Chicago, IL 60637

Civil Engineering

American Society of Civil
Engineers
345 East 47th Street
New York, NY 10017

Certified Engineering Technician

American Society of Certified
Engineering Technicians
2029 K Street, N.W.
Washington, D.C. 20006

Engineering News-Record

McGraw-Hill Book Company,
Inc.
330 W. 42nd Street
New York, NY 10036

Consulting Engineer

Consulting Engineers Council of
the USA
1155 15th Street, N.W.
Washington, D.C. 20005

APPENDIX B

RECOMMENDED READING

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Student chapters of the American Society of Civil Engineers sponsor many enjoyable and educational activities, such as this field trip to a bridge construction site.

APPENDIX C

ADDITIONAL INFORMATION

A very complete and useful series of brochures and short articles on various aspects of civil engineering careers is available from the Engineers' Council for Professional Development. A partial listing of these items is given below.

Individual requests for single copies, from students and teachers, for guidance material (except for those marked*) will be honored at no charge.

All requests for these materials should be made to:

Engineers' Council for Professional Development
Publications Office
345 East 47th Street
New York, NY 10017

EC-12-Manual for Engineers Service as Career Advisers. A guide for engineers interested in working with young people. Contains charts and complete basic guidance reference list. Out of print; revised edition available July 1977.*

EC-13-After High School—What? 5 pp., 15 cents. Brief summary of nature of work qualifications, and education for engineers and technicians. Explains how engineering differs from a career in science.

EC-14-Career Choice. Aid in Engineering/Engineering Technology, 1975, 16 pp. 35¢. A self-administered questionnaire about the aptitude, interest and determination needed to pursue a career as an engineer or engineering technologist. Provides general information.

EC-15-A Primer on Financial Aid for Students. 1975, 4 pp., no charge. Presents the 12 steps and time-table most likely to bring about the best results in securing financial assistance for educational purposes.

EC-16-Directory of Engineering Guidance Materials and Programs. 1975, 12 pp., 15 cents. Information about the nature and scope of opportunities which exist in engineering and technology fields. List societies which publish guidance material and ECPD endorsed programs providing experience opportunities.

EC-18-Audiovisual Guidance Aids. 1974, 2 pp., no charge. Describes various audiovisual guidance aids available on loan from ECPD's New York Office. Includes films, slides, and posters.

EC-19-Guidance Counselor Kit. 1973, \$5.00. Compilation of the top guidance publications of ECPD and its constituent societies. Over 15 different brochures in a special file folder. Ideal for counselor or of library reference shelves.*

EC-20-Accredited Programs Leading to Degrees in Engineering in the United States. Reprinted from current ECPD Annual Report, 25 cents. Lists all accredited programs by institution.

EC-60-Engineering Guidance Ideas—Five Thoughts. 1969, 44 pp., \$1.00. Four papers, from a counselor, a science teacher, a department chairman, and a school principal, reflect the feeling of these school personnel toward engineering guidance. A fifth paper, by Larry Down, states the program of ECPD's Guidance Committee.

EC-62-Engineering: Creating a Better World. 1970. 20 pp. 25 cents. Designed for distribution to elementary school children. Describes engineering and its relevance to society.

EC-68-Make Your Career Choice Engineering. 1974, 20 pp., 35 cents. A discussion of the high school and college preparation for entry into the engineering profession. A brief description of various disciplines is presented.

EC-69-The Engineering Team. 1974. 13 pp., 25 cents. A description of work done by and the preparation for engineers, scientists, technologists, craftsmen, and technicians.

EC-70-Engineering. 1974. A series of 6- or 8-page envelope-size brochures describing various engineering disciplines. Single copies free; \$5.00 per hundred. Available with special imprint (maximum 5 lines). Minimum order \$75.00 per thousand. Please use proper designation for the series. 70 CE: Civil Engineering.

EC-72-Womengineer. 1974. 18 pp., 25 cents. A comprehensive

description of the role of women in engineering and the need for more in the profession. Well illustrated.

EC-73-Making It In Engineering. 1975, 8 pp., 25 cents. Five members of minority groups are portrayed as role models and describe how they made the engineering profession a personally rewarding career.

EC-74-Engineering: Lost in the Shuffle? 1974, 54 pp., 75 cents. A compilation of 18 articles on engineering guidance and counseling containing many source materials on personnel and available literature. A special reprint of "Engineering Education," Vol. 64, No. 7, April, 1974.

JUNIOR ENGINEERING TECHNICAL SOCIETY PUBLICATIONS

EC-80-THE JETS PROGRAM. 8 pp., no charge. An explanation of the Junior Engineering Technical Society's program for secondary school students interested in engineering and technology.

EC-81-THE JETS CHAPTER HANDBOOK. 353 pp., \$7.50 (free to chapters and advisors). A manual covering organization and management of JETS chapters and projects. Includes a bibliography of Engineering Career Information. Add \$2.50 for binder.

EC-82-JUNIOR ENGINEERING TIMES SPECIAL. 9 issues, 4 or 6 pp. newsletter, \$2.50 per year. Presents a study program each month, essays on engineering, chapter news, and calendar of coming events. Also includes 2 p. newsletter *ENGINEERING** prepared by The National Executive Committee for Guidance (NECG).

APPENDIX D

ACCREDITED SCHOOLS

Over 160 universities and colleges currently offer programs in civil engineering in the United States.

The prospective student in civil engineering will do well to investigate in depth any school that he is considering attending. As recommended in Chapter 2, such an investigation should include an evaluation of the training and professional background of the faculty, and school facilities and laboratory instrumentation available to the engineering students. Admittedly this type of investigation is somewhat difficult for the novice or entering student who is seldom familiar with acceptable standards for technical details of this type. In order to assist in this matter to some degree, there are professional agencies that look closely at these schools' programs. While these accrediting agencies do not rank the schools or their programs, they do list those programs which are acceptable with respect to the standards as established by the engineering profession.

The Engineers Council for Professional Development (ECPD) conducts such an accreditation based on a review of course offerings, an evaluation of faculty capabilities, and on-site inspections of applicant institutions. The prospective civil engineering student can be confident of receiving an adequate preparation for professional growth at any ECPD accredited school.

Further, some schools offer programs which are more limited than the ideal combination of academic work and training recommended by ECPD, but which may be sufficient to win accreditation by regional educational review organizations.

Listed below are the current (1976) ECPD-accredited programs in civil engineering.

ACCREDITED PROGRAMS BY INSTITUTIONS

Explanatory Notes:

Characteristics of the accredited program are noted after each program listing by combinations of the following symbols:

- d—day program
- e—evening program
- c—co-operative program
- a—advanced level
- b—basic level
- m—program terminates in master's degree
- 4—four-year program
- 5—five-year program

Air Force Institutes of
Technology
Wright-Patterson Air Force Base,
OH 45433

ma

University of Akron
Akron, OH 44325

d4b, d5cb

The University of Alabama
University, AL 35486

d4b

The University of Alaska
Fairbanks, AK 99701

d4b

Arizona State University
Tempe, AZ 85281

d4b, ma

University of Arizona
Tucson, AZ 85721

d4b

University of Arkansas
Fayetteville, AR 72701

d4b

University of Auburn
Auburn, AL 36830

d4b, cb

University of Bradley
Peoria, IL 61625

d4b, cb

Brigham Young University
Provo, UT 84602

d4b, ma

Brown University
Providence, RI 02912

d4b

Bucknell University
Lewisburg, PA 17837

d4b

California State Polytechnic
University, Pomona

Pomona, CA 91768

d4b

California State University Chico
Chico, CA 95929

d4b

California State University,
Fresno

Fresno, CA 93740

d4b

California State University, Long
Beach

Long Beach, CA 90840

d4b

Sacramento California State
University

Sacramento, CA 95819

d4b

150 *Opportunities in Civil Engineering*

- | | |
|--|--|
| University of California
Berkeley, CA 94720
d4b, cb | Cornell University
Ithaca, NY 14850
d4b, cb, ma |
| University of California
Davis, CA 95616
d4b | University of Dayton
Dayton, OH 45469
d4b |
| University Carnegie-Mellon
Pittsburgh, PA 15213
d4b | University of Delaware
Newark, DE 19711
d4b |
| Case Western Reserve University
Cleveland, OH 44106
d4b | University of Denver
Denver, CO 80210
d4b, cb |
| Catholic University of America
Washington, DC 20017
d4b | University of Detroit
Detroit, MI 48221
dc5b |
| University of Cincinnati
Cincinnati, OH 45221
dcb | Drexel University
Philadelphia, PA 19104
dc5b |
| The Citadel
Charleston, SC 29409
d4b | Duke University
Durham, NC 27706
d4b |
| Clarkson College of Technology
Potsdam, NY 13676
d4b, ma | University of Florida
Gainesville, FL 32611
d4b |
| Clemson University
Clemson, SC 29631
d4b | George Washington University
Washington, DC 20052
d4b |
| Cleveland State University
Cleveland, OH 44115
d4b, cb | Georgia Institute of Technology
Atlanta, GA 30332
d4b, eb, cb; dma, ema, cma |
| Colorado State University
Fort Collins, CO 80521
d4b | University of Hawaii
Honolulu, HI 96822
d4b |
| University of Colorado
Boulder, CO 80302
d4b | University of Houston
Houston, TX 77004
d4b, cb |
| Columbia University
New York, NY 10027
d4b, d5b | Howard University
Washington, DC 20001
d4b, cb |
| University of Connecticut
Storrs, CT 06268
d4b | University of Idaho
Moscow, ID 83843
d4b |
| The Cooper Union
New York, NY 10003
d4b | Illinois Institute of Technology
Chicago, IL 60616
d4b, cb |

University of Illinois at
Urbana-Champaign
Urbana, IL 61801

d4b, cb

Iowa State University
Ames, IA 50010

d4b

University of Iowa
Iowa City, IA 52240

d4b

Kansas State University
Manhattan, KS 66506

d4b

University of Kansas
Lawrence, KS 66045

d4b

University of Kentucky
Lexington, KY 40506

d4b

Lafayette College
Easton, PA 18042

d4b

Lamar University
Beaumont, TX 77710

d4b

Lehigh University
Bethlehem, PA 18015

d4b

Louisiana State University
Baton Rouge, LA 70803

d4b

Louisiana Tech University
Ruston, LA 71270

d4b

University of Louisville
Louisville, KY 40208

dc5m

Loyola Marymount University
Los Angeles, CA 90045

d4b

University of Maine at Orono
Orono, ME 04473

d4b

Manhattan College
Riverdale, NY 10471

d4b

Marquette University
Milwaukee, WI 53233

d4b, cb, cb

Massachusetts Institute of
Technology

Cambridge, MA 02139

d4b

University of Massachusetts
Amherst, MA

d4b

Memphis State University
Memphis, TN 38152

d4b

Merrimack College
North Andover, MA 01845

d4b

University of Miami
Coral Gables, FL 33124

d4b

Michigan State University
East Lansing, MI 48823

d4b

Michigan Technological
University

Houghton, MI 49931

d4b

University of Michigan
Ann Arbor, MI 48104

d4b

University of Minnesota
Minneapolis, MN 55455

d4b

Mississippi State University
Mississippi State, MS 39762

d4b, cb

University of Mississippi
University, MS 38677

d4b

University of Columbia-Missouri
Columbia, MO 65201

d4b

152 *Opportunities in Civil Engineering*

University of Missouri-Rolla
Rolla, MO 65401

d4b

Montana State University
Bozeman, MT 59715

d4b

University of Nebraska
Lincoln, NB 68588

d4b

University of Nevada-Reno
Reno, NV 89507

d4b

University of New Hampshire
Durham, NH 03824

d4b

University of New Haven
West Haven, CT 06516

d4b, cb

New Jersey Institute of
Technology

Newark, NJ 07102

d4b, cb

New Mexico State University
Las Cruces, NM 88001

d4b

University of New Mexico
Albuquerque, NM 87131

d4b

New York, City College of the
City University

New York, NY 10031

d4b, cb

New York at Buffalo, State
University

Buffalo, NY 14214

d4b

New York University

See Polytechnic Institute of New
York

(Due to merger with Polytechnic
Institute of Brooklyn programs
phasing out students attend
Polytechnic)

d4b, cb

North Carolina State University
at Raleigh

Raleigh, NC 27607

d4b, cb, ma

North Dakota State University
Fargo, ND 58102

d4b

University of North Dakota
Grand Forks, ND 58201

d4b

Northeastern University
Boston, MA 02115

dc5b

Northern Arizona University
Flagstaff, AZ 86001

d4b, cb

Northwestern University
Evanston, IL 60201

d4b, cb

Norwich University
Northfield, VT 05663

d4b

University of Notre Dame
Notre Dame, IN 46556

d4b

Ohio Northern University
Ada, OH 45810

d4b

Ohio State University
Columbus, OH 43210

d4b

Ohio University
Athens, OH 45701

d4b

Oklahoma State University
Stillwater, OK 74074

d4b

University of Oklahoma
Norman, OK 73069

d4b

Oregon State University
Corvallis, OR 97331

d4b

University of the Pacific
Stockton, CA 95211
d4b
Pennsylvania State University
University Park, PA 16802
d4b
University of Pennsylvania
Philadelphia, PA 19174
d4b
University of Pittsburgh
Pittsburgh, PA 15213
d4b
Polytechnic Institute of New York
Brooklyn, NY 11201
d4b, eb
Prairie View A & M University
Prairie View, TX 77445
d4b
Princeton University
Princeton, NJ 08540
d4b
University of Puerto Rico
Mayaguez, PR 00708
d5b
Purdue University
W. Lafayette, IN 47907
d4b, cb
Rensselaer Polytechnic Institute
Troy, NY 12181
d5mb, cmb
University of Rhode Island
Kingston, RI 02881
d4b
Rice University
Houston, TX 77001
d5mb
Rose-Hulman Institute of
Technology
Terre Haute, IN 47803
d4b
Rutgers University-The State
University
New Jersey
New Brunswick, NJ 08903
d4b, d5b

St. Martin's College
Olympia, WA 98503
d4b
San Diego State University
San Diego, CA 92182
d4b
San Jose State University
San Jose, CA 95192
d4b
Santa Clara, University
Santa Clara, CA 95053
d4b
University of South Carolina
Columbia, SC 29208
d4b, ma
South Dakota School of Mines
and Technology
Rapid City, SD 57701
d4b
South Dakota State University
Brookings, SD 57006
d4b
Southeastern Massachusetts
University
North Dartmouth, MA 02747
d4b
University of Southern California
Los Angeles, CA 90007
d4b
Southern Methodist University
Dallas, TX 75275
d4b, cb, ma
Southern University
Baton Rouge, LA 70813
d4b, cb
University of Southwestern
Louisiana
Lafayette, LA 70501
d4b
Stanford University
Stanford, CA 94305
d4b
Syracuse University
Syracuse, NY 13210
d4b

Tennessee State University Nashville, TN 37203 d4b	Utah State University Logan, UT 84322 d4b
Tennessee Technological University Cookeville, TN 38501 d4b, cb	University of Utah Salt Lake City, UT 84112 d4b
University of Tennessee Knoxville, TN 37916 d4b, cb	Valparaiso University Valparaiso, IN 46383 d4b
Texas A & M University College Station, TX d4b, cb	Vanderbilt University Nashville, TN 37203 d4b
Texas Tech University Lubbock, TX 79409 d4b	University of Vermont Burlington, VT 05401 d4b
University of Texas at Arlington Arlington, TX 76010 d4b	Villanova University Villanova, PA 19085 d4b
University of Texas at Austin Austin, TX 78712 d4b	Virginia Polytechnic Institute and State University Blacksburg, VA 24061 d4b, cb
University of Texas at El Paso El Paso, TX 79968 d4b	University of Virginia Charlottesville, VA 22901 d4b
University of Toledo Toledo, OH 43606 d4b	Washington State University Pullman, WA 99163 d4b
Tri-State University Angola, IN 46703 d4b, cb	University of Washington Seattle, WA 98195 d4b
Tufts University Medford, MA 02155 d4b	Washington University St. Louis, MO 63130 d4b, d5cb
Tulane University New Orleans, LA 70118 d4b	Wayne State University Detroit, MI 48202 d4b, cb
Union College Schenectady, NY 12308 d4b	West Virginia Institute of Technology Montgomery, WV 25136 d4b, cb
United States Air Force Academy USAF Academy, CO 80840 d4b	West Virginia University Morgantown, WV 26506 d4b

University of Wisconsin-Madison
Madison, WI 53706

d4b

University of
Wisconsin-Platteville
Platteville, WI 53818

d4b

Worcester Polytechnic Institute
Worcester, MA 01609

d4b

University of Wyoming
Laramie, WY 82071

d4b

Youngstown State University
Youngstown, OH 44503

d4b, cb

ABOUT THE AUTHORS

D. Joseph Hagerty is an associate professor of civil engineering at the University of Louisville, Speed Scientific School, College of Engineering. He is active in teaching, research and consulting in civil and environmental engineering. Dr. Hagerty has collaborated with several colleagues, including Dr. John Heer, in writing several textbooks on environmental engineering. He has been recognized by the American Society of Civil Engineers and the National Society of Professional Engineers for his contributions in community service and student counseling. Dr. Hagerty has served as consultant to the United States Environmental Protection Agency, the United States Army Corps of Engineers and state and local governments.

John E. Heer, Jr., is chairman and professor, department of civil engineering, University of Louisville, Speed Scientific School. Dr. Heer has been an engineering educator for more than 25 years and has written four textbooks on civil and environmental engineering. His outstanding contributions as an engineering educator have won him widespread recognition by his colleagues in the engineering profession. In the course of his consulting activities with international environmental organizations as well as federal, state, and local governments, Dr. Heer has visited many of the nations of North America and Western Europe. In addition to being chairman of the department of civil engineering at the University of Louisville, he also directs the civil engineering technology program at the University of Louisville.

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